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AN
E S S A Y
ON
C O M E T S,
In T W O P A R T S.

P A R T I.

CONTAINING an Attempt to explain the Phænomena of the TAILS of COMETS, and to account for their perpetual Opposition to the SUN, upon philosophical Principles.

P A R T II.

POINTING out some important Ends for which these TAILS were probably designed : Wherein it is shewn, that, in Consequence of these curious Appendages, COMETS may be inhabited WORLDS, and even comfortable Habitations ; notwithstanding the vast Excentricities of their Orbits.

The Whole interspersed with Observations and Reflections on the SUN and primary PLANETS.

By ANDREW OLIVER, JUN. ESQ.

In human Works, though labour'd on with Pain,
A thousand Movements scarce one Purpose gain ;
In God's, one single can it's End produce ;
Yet serves to second too some other Use.

POPE'S ESSAY ON MAN.

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MDCCLXXII.

AN

Y A S S

ON

S T E

T W A R T



TO
JOHN WINTHROP, LL.D.

HOLLISIAN PROFESSOR

Of the MATHEMATICS, and NATURAL PHILOSOPHY;

AND

FELLOW of the CORPORATION, of HARVARD-COLLEGE;

**MEMBER of the AMERICAN PHILOSOPHICAL SOCIETY
Of PHILADELPHIA;**

AND

FELLOW of the ROYAL SOCIETY.

The following ESSAY,

**AS an Acknowledgment of the Obligations which
result from an Initiation, under his Instruction, in
the Study of those Sciences which more immediately
belong to his Province : In Reliance upon his Pa-
tronage of a Treatise, which owes its Publication
to his Candor and Approbation : And, with all
due Deference to his superior Judgment ; is grate-
fully inscribed, by**

His Obliged Friend,

And

Most Humble Servant,

The AUTHOR

JOHN WINTHROP

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The AUTHOR.

P R E F A C E.

THE design of the following Essay was, partly to eradicate some absurd notions which have been handed down from the darkest periods of antiquity, and which are still entertained by some, upon the appearance of a Comet; and to remove the apprehensions which may have been excited in the minds of others, even by the writings of some great men among the moderns: And partly to offer to those who indulge themselves in more abstruse researches after the operations of natural causes, a few hints, the prosecution of which may enlarge the field of philosophical speculation, and open to all a new source for adoration of the wisdom and beneficence of that Being, who has made nothing in vain, and has disposed the various parts of the Universe by weight and measure. It may therefore be presumed, that, if the Author is so happy as to be understood by the generality of his readers (which he has aimed at throughout the whole) the gentlemen of science will pardon those minute discussions, which they may judge unnecessary, and that they will weigh with impartiality the arguments which may be offered for their consideration, overlook any immaterial inaccuracies, which may have arisen through inadvertency, and point out and refute with candour any mistakes which he may have fallen into,

IT is now well known to astronomers that the motions of Comets are regulated by the universal law of gravitation, and that they regard the Sun as the common center of all their motions, equally with the Planets, although they ar

more numerous, and apparently distinct in species from them. The Planets, since the discovery of the Satellites or Moons which attend some of them, are generally, and with the highest reason supposed to be inhabited Worlds like the Earth.—Whereas it has been thought even by some of the greatest modern astronomers, that the extremes of heat and cold to which Comets are alternately exposed in the different parts of their orbits, are irreconcilable with the notion of their being fit habitations for any material race of beings whatever. They are to this day regarded by the bulk of mankind, either as portentous meteors, exhibited only to threaten war, famine or pestilence to the inhabitants of the Earth; or as fiery globes which move thro' the Heavens at random, and might fortuitously come across the Earth in its way, to its no small detriment, if not to the destruction of its inhabitants; or lastly as penal worlds, ordained to a perpetual chaotic state, whose inhabitants are condemned to be frozen and burned alternately, at their aphelia and perihelia; agreeable to Milton's idea of the punishment of apostate spirits; speaking of whom he says,

“ They ———— feel by turns the bitter change
Of fierce extremes, extremes by change more fierce,
From beds of raging fire to starve in ice
Their soft æthereal warmth, and there to pine
Immovable, infix'd, and frozen round
Periods of time, thence hurried back to fire.”

PARADISE LOST, Book II.

THE first of these opinions was exploded long ago by Seneca; who, instead of regarding Comets as transient meteors, on the contrary ranks them with “ the eternal works of nature.” The second directly contradicts the
idea

idea of a divine superintendancy, and falls of course, in the minds of those who entertain any just apprehension of the providential care of the great Author and Governor of the Universe. And as to the last, with what colour of reason can we suppose that the Creator would provide upwards of fifty Worlds (for so many different Comets and more there certainly are) solely for the punishment of the incorrigible inhabitants of five or six Planets only? On the contrary does it not redound more to his honour, to consider these bodies as so many inhabited Worlds, provided with every necessary for the comfortable subsistence of innumerable inhabitants, rational and irrational, like the Earth? Or as Doctor Young (speaking of the CREATOR and his works) beautifully expresses himself;

“ Darts not HIS Glory a still brighter Ray,
The less is left to Chaos and the Realms
Of hideous Night? —————

NIGHT THOUGHTS, Night 9.

T H E reader will find (in the introduction) that the consideration of the subject, in this light, was first started by Hugh Williamson, M. D. of Philadelphia, in a treatise that was published in one of the weekly papers; which, as it contained some new thoughts, the pursuit of which (it was judged) would tend to the improvement of natural philosophy, first induced the Author to undertake the following Essay, upon a subject indeed which, till then, he had but little attended to: He therefore hopes that, if any observations or reflections shall turn up, in the course of it, which may merit the attention of his readers, and may have escaped the notice of others, they may in some measure
alone

atone for the many defects, of which he is apprehensive, and which are submitted to those who have made greater proficiency in natural knowledge, than he pretends to, to rectify.

DIVERS of the Author's friends, who are gentlemen of speculation and learning, perused the Essay in manuscript, upon whose approbation of it, and at whose request, he was induced to consent to its publication: But when the unexpected number of subscribers, and their respectable characters in general, came to his knowledge, his diffidence of its title to their favourable reception was naturally increased, which would have excited in his mind a proportionable reluctance to its appearance abroad, lest their expectations should be disappointed, had he not been fully persuaded, that the greatest candour was naturally to be expected from those who are the best judges of the subject; especially, as the treatise contains nothing more than an attempt to discover some philosophical truths, the knowledge of which may tend to promote the cause of Science, and thereby may possibly be of some service to mankind.

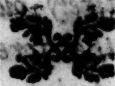
IT was with pleasure He found that Doctor Gowin Knight, F. R. S. had attempted to account for the phenomena of the tails of Comets from the same principle which he has endeavoured to establish in the following pages, viz. a mutual repellency, subsisting between the atmospheres of the heavenly bodies: As the Doctor, when he wrote his treatise, was engaged in the general solution of all the phenomena in Nature, by the help of two universal principles, viz. Attraction and Repulsion, he but slightly touched upon the particular phenomena, now under consideration; accordingly what he says upon the subject is

very

very short, being included within the compass of a single corollary, which arises out of a long chain of deductions from the supposed properties of an imaginary repellent fluid, uniformly distributed throughout the infinity of space; the existence of which, however probable, has never been proved: When the author wrote that part of the *Essay* which is confined particularly to this subject, Doctor Knight's solution was entirely out of his mind, if he had ever seen it before. He therefore took a different course to establish the principle, deducing it from the known properties of air, a real fluid, the existence of which we are certain of, from the immediate testimony of our senses, as we are of its properties from innumerable experiments. This element differs essentially from the Doctor's universal fluid, which indeed he supposes to consist of particles mutually repellent, like those of air, but so inconceivably rare, that a quantity of it sufficient to fill the whole space occupied by the solar System, might not weigh one single grain (*Knight's Essay*, page 15): Air on the contrary, is a heavy fluid, the pressure of which, merely from its gravity, is capable of giving great pain to those who may attempt to sustain its weight, in pneumatical experiments.

HOWEVER, it does not follow, that if air, considered as a fluid sui generis, is sufficient immediately to account for the phenomena before us, we should therefore exclude the agency of another, upon whose existence and properties (if proved) the properties of air itself may possibly depend. By supposing such an universal repellent fluid, Doctor Knight has very curiously accounted for many of the phenomena of Nature, which are so common as to be but little attended to; such as fluidity, elasticity, magnetism, &c. And, whether the mutual repellency of the particles

particles of air does (as he supposes) or does not depend upon the presence of the same fluid, the conclusion will equally follow that, The aerial atmospheres of the heavenly bodies are mutually repellent.



The reader is desired to make the following corrections, the necessity and propriety of which were not discovered in season to save him this trouble, viz.

In Page 22, Line 4, for, by the incumbent weight of the whole atmosphere, to read, by the weight of the whole incumbent atmosphere. In Page 38, Line 7, from the bottom, for, all fluids which tend, &c. to read, every fluid the several parts of which tend, &c. In Page 42, Line 3, from the bottom, for, atmospheres, to read, atmospheres. In Page 78, Line 3, for, decrease of its atmosphere, to read, decrease of the density of its atmosphere. In Page 80, Line 17, to read, whereby the presence of the Sun by day; and in Line 19 of the same Page, after the word Comet, to insert these words, viz, than when it is in the remote parts of its orbit.

ESSAY

INTRODUCTION

TO THE

ESSAY.

IN the month of *September*, 1769, during the appearance of a remarkable Comet, Doctor *Hugh Williamson* of *Philadelphia* favoured the publick with a treatise on the subject of the following Essay, which was read before, and published by order of the Philosophical Society in that city. This piece contained some curious hints, well deserving the attention of the friends of science: Particularly, that Comets, as well as the Planets, may be *habitable Worlds*; that the comfortable state the inhabitants of the various globes of the solar system enjoy, may not depend merely upon their several distances from the Sun; and, that although the rays of the Sun may be absolutely necessary to the very existence of planetary heat, yet the temperature of that heat may depend upon the densities of the atmospheres surrounding the several globes; whereby the Comets, even in their *aphelia*, may be rendered comfortable habitations, by means of the vast atmospheres which attend them, and which, when they might become detrimental to their inhabitants, as when they are in the neighbourhood of the Sun, are, by the momentum of the Sun's rays, or by some other cause, thrown off to immense distances behind them.

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THE

THE perusal of this treatise occasioned the following attempt to establish the doctrine of the habitability of Comets, advanced therein by Doctor Williamfon.

We differ indeed in our hypotheses to account for the phenomena of their tails ; but whichsoever may be the true one, all *his* conclusions, relative to the densities of their atmospheres in the various parts of their orbits, may equally follow.

THE Doctor's hypothesis, which is the same with *Kepler's*, supposes the atmosphere of a Comet, by the velocity and consequent momentum of the Sun's rays, to be propelled through immense spaces behind its body, whereby the tail is formed, which is rendered visible by reflecting those rays.

THIS, it must be confessed, seems to be as natural and easy a solution as any one hitherto offered ; and might be embraced as such, had any one experiment ever been produced to prove the rays of light endued with any such power, even upon the most minute corpuscles, or the most rarefied vapor. Sir *Isaac Newton* passes it by with little more than a bare mention, (*Princip.* under Prop. XLI. Book III.) which, as it is so plausible, is difficult to account for ; especially as he fills pages to refute others, that are almost self-evidently absurd. This hypothesis, however, has never been confirmed by any one experiment, although an age has elapsed since *Kepler's* time, during which experimental philosophy has been at its zenith. Therefore, as Mr. Professor *Wintbrop*, in his lectures on Comets, observes, " much stress should not be laid
 " upon

“ upon it, as we know of no parallel instance in nature to support it.” The hypothesis contained in this Essay is founded upon a mutual repellency, which is supposed to subsist between the several atmospheres of the heavenly bodies ; which is deduced from the repellency of the particles of air, of which the atmosphere of the earth, and those which surround the other globes, are composed. That our atmosphere consists of particles thus repellent, is certain from the whole system of pneumatics, as no one experiment, in that useful, instructive and entertaining branch of natural philosophy, can be performed, which does not depend upon this property of AIR. That the Sun and Planets have similar atmospheres, will appear in the following pages.

SIR *Isaac*, after having refuted several hypotheses, which had been raised by others, to account for the ascent of Comets tails from the Sun, at length rather hints at, than substitutes one of his own ; as he asserts nothing positively, but only offers a query for the consideration of his readers. Therefore it is hoped that nothing here advanced will be considered as a *vain, rash* attempt to confute that illustrious author. “ The ascent of smoke in a chimney (says he) is owing to the impulse of the air with which it is entangled. The air, rarefied by heat, ascends because its specific gravity is diminished, and in its ascent carries along with it the smoke with which it is engaged.” (Princip. ubi supra). To which he adds the following query : “ And why may not the tail of a Comet rise from the Sun after the same manner ?” Previous to an answer to this query, let us consider more particularly the

the causes of the ascent of vapors in our atmosphere. It is indeed beyond doubt, that to the cause above assigned, by Sir *Isaac Newton*, is in a great measure owing the rise of smoke from common fire; from which, if enkindled in the open air, it will curl up in broad volumes, spreading as it rises; but if confined in a chimney, the rarefied air having but one way to expand itself, viz. through the funnel, the more condensed air in the room below driving it upwards, together with the smoke engaged with it, it ascends in a strait course, with a greater velocity, and apparently to a greater height than when unconfined.

BUT this is not the sole, nor yet the principal cause of the ascent of vapors in general, but rather an accidental one, which increases their velocity when already on the wing. For, *really*, the *causa sine qua non* of their ascent, in a quiescent atmosphere, is the difference of the specific gravities of those vapors, and the air they float in*; the former, being generally lightest, continue rising till they arrive at that region of the atmosphere in which the densities of both are equal.— There they gather and form into clouds; there they remain suspended, or are driven by winds in directions parallel to the surface of the Earth, until some casual rarefaction of the air, the meeting of contrary winds, or of electrified clouds differently charged, cause them, either to condense imperceptibly, and fall in dews or gentle rains, or to rush more violently together, and precipitate in showers, according to the nature of the cause by which they are actuated. The smoke of a chimney

* How they are generated, and detached from the surfaces of bodies, is a proper subject for an enquiry by itself, but foreign here.

chimney is for the most part lighter than the circum-ambient air it ascends through, otherwise it would descend again as soon as it could disengage itself from that column of air which carried it up ; in consequence of which, life would be very uncomfortable in large, populous cities ; for, at times, the air with us is so rarefied that the smoke does in fact thus descend, and hover just above the surface of the Earth, to the no small annoyance of the eyes and lungs of those who breathe in such an impure medium. Were it necessary, experiments in pneumatics might be recited, which prove that air, near the surface of the Earth, is in general denser or heavier than the smoke and other vapors which float therein ; which are here omitted, as it is presumed the fact will not be disputed.

Now, if the tail of a Comet rises from its head, or rather from the Sun, in the same manner as smoke does from fire with us, and from a similar cause, the æthereal medium, thro' which it ascends, must be nearly of the same density with the vapors of the tail ; otherwise the latter could not float in, nor get so entangled with it as to be carried up thereby through distant regions of the Heavens ; but that the tails may ascend to such amazing heights, as some of them do, we must necessarily suppose their specific gravities much less than that of the æther itself.

WHAT then becomes of the free celestial spaces ? in which Sir Isaac says,—“ not only the *solid bodies* of “ *the Planets and Comets*, but also *the extremely rare vapors of Comets tails*, maintain their rapid motions with “ *great freedom—without resistance.*” (Ibid.) Soon after

after he adds, “—the tails—retaining their own proper motion” (i. e. the motion they had in common with their heads) “and in the mean time gravitating towards the Sun, must be revolved in ellipses round the Sun in like manner as the heads are, and by that motion always accompany their heads.” Now, although the æther may be supposed so extremely rare, as that the solid globes may revolve thro’ it for many ages, without any sensible impediment, or, as *Sir Isaac* says, “above ten thousand years;” yet, as the tails must, upon this hypothesis, be nearly of the same specific gravity with that æther, how can *they* “maintain their rapid motions through it *without resistance*, and revolve in ellipses round the Sun together with their heads”? That this is utterly impossible, appears from the reasoning of *Sir Isaac himself*, throughout the whole of his VII Section *Principia Book II.* intituled, *Concerning the motion of fluids, and the resistance made to projected Bodies*: According to which reasoning the projectile motions of these vapors would be very soon destroyed, and the Comet in its regress from the Sun would necessarily leave them behind as they rose from the head, in consequence of the resistance of this æthereal medium: Therefore, whenever the Comet became visible, after the perihelion, it would have a tail as before, but *reversed*, appearing, like a lucid beam, to stream away from the head *towards* the Sun, till it were confounded with the twilight. But this is contrary to all observations; for the projection of a Comet’s tail, after its perihelion as well as before, is both really and apparently *from* the Sun, excepting a small deviation towards the parts from whence the Comet last came: Which deviation is by no means owing
to

to the resistance of any medium it passes through, but is perfectly consistent with its several parts retaining the motion they had in common with their head when they began to ascend, and “revolving *freely* in ellipses “round the Sun together with their head.” For, the remote parts of the tail making a larger sweep through the Heavens than their head, while the latter takes a shorter turn round the Sun at its perihelion, must necessarily be longer in describing the same angular motions round the Sun than the globe itself; consequently must be deflected from the direct opposition to the Sun, and the whole tail be incurvated towards the perihelion position lately passed; and this upon the supposition that both head and tail move *freely* through a perfect *vacuum*. This incurvation of the tail lessens as the Comet recedes from the Sun, ’till at length it recovers its opposition as at first. Now, as these phenomena agree perfectly with the motion of a Comet’s tail through spaces *void of resistance*, they are utterly inconsistent with the supposition of its moving through a medium of equal or greater density than itself, or in any other *resisting medium* whatever; for according to this celebrated author (Princip. Sect. VII. Book II. Prop. XXXVIII. Cor. 4.) if the head or solid globe of the Comet moved in a fluid of the same density with itself, it would lose half its motion before it could describe the length of two of its diameters, consequently it would soon lose the whole. The vapors of the tail rising (upon his hypothesis) in a medium of nearly the same density with themselves, would in like manner, from the resistance of that medium, lose all the projectile motion they derived from the head, full as soon as the head would lose its own motion in the former case.

SIR

SIR *Isaac* concludes said VII Section with the following words, "The *resistance* in every fluid is as the motion excited by the projectile in the fluid ; and cannot be less in the most subtile æther, in proportion to the density of that æther, than it is in air, water, and quicksilver, in proportion to the densities of those fluids."

UPON the whole, then, it necessarily follows, that the æthereal spaces through which the *extremely rare vapors of a Comet's tail revolve freely with its head in ellipses round the Sun*, must be perfect *vacuums* as to all the purposes of *resistance* ; and consequently, that the rays of light themselves in no wise impede the freedom of their motion, even when in the neighbourhood of the Sun.

ALL that is desired of the reader is, that he will peruse the following sheets with candour, and not pronounce sentence until he has fairly weighed the evidence produced in support of the several propositions therein contained ; upon the strength, or through the deficiency of which, they must stand or fall.



ESSAYS ON COMETS.

PART I.

A COMET consists of two parts which fall under our observation, viz. a solid, spherical, opaque body, which, like the planets, shines by reflecting the light of the Sun, and no way differs in appearance from a planetary globe; this is by astronomers called the *nucleus*: Also a very extensive atmosphere; which, from the form it usually exhibits to us, is called the *tail*, and commonly exhibits a faint beam of light, which diverges as it recedes from the head, and often apparently extends thro' distant constellations, when it nearly resembles those momentary corruscations which shoot upwards from the horizon towards the zenith, during the appearance of an *aurora borealis*, or northern light. This tail increases in length as the Comet approaches the

C

Sun,

Sun, *et vice versa* ; and its direction is always nearly in opposition to the Sun. Sometimes indeed the cometic atmosphere assumes a different form, surrounding the nucleus equally on every side like a thin cloud or mist, or, as some have fancied, like a bush of hair ; whence the Comet has been denominated *crinite* or hairy. The latter is the usual appearance of a Comet when first discovered in its descent toward the Sun, provided the Sun and Comet be in opposite hemispheres ; and may take place in some other situations, agreeable to the rules of optics, even when to spectators in other parts of our System, the Comet may exhibit a tail of an enormous length.

It has been sufficiently demonstrated by Sir *Isaac Newton*, Dr. *Halley*, and others, that these bodies are, in common with the other globes of the solar system, subject to the law of mutual gravitation, and that they regard the Sun as their common center of gravity, and consequently move round him in *conic-sections*, carrying their atmospheres or tails along with them. Their orbits differ widely from *circles* on the one hand ; on the other, since the discovery of the Newtonian method of computing their trajectories from observations, they have never been found to deviate into *hyperbolas* ; and though their observed places, in the small parts of their orbits in which they are visible to us, agree with their computed places, upon the supposition that they move in *parabolas* ; yet, as the periodical revolutions of some of them have been ascertained by their regular returns after certain intervals, it is agreed by astronomers, that their paths are truly *elliptical*, though very excentric ;
such

such *ellipses*, near the extremities of their transverse axes, differing but insensibly from *parabolas*. All that is attempted in this Essay, is,

1. To account for the phænomena of the tails of Comets, upon philosophical principles : And then,

2. To point out some ends to which they seem adapted, and for which they are probably designed.

SIR *Isaac Newton* has sufficiently proved that these tails consist of a fluid matter, extremely rare, emitted from their heads upon their approach to the Sun, which is rendered visible by reflecting his rays * : But what cause there may be existing in nature, capable of projecting the cometic atmospheres through such immense spaces, is a question which still remains to be solved, no satisfactory account having hitherto been offered to the publick. In order therefore, to a rational solution of this curious phænomenon, *the tail of a Comet*, the following propositions, observations, &c. are submitted to the candid perusal of the reader : First premising, that when a subject, under consideration, is in its nature purely physical, it is to be presumed that strict, mathematical demonstration will not be expected.

WE shall now endeavour to prove the following propositions.

FIRST, THAT the primary Planets, the Comets, and the Sun, are all surrounded with atmospheres.

SECONDLY,

* Princip. Book III. under Prop. XLI.

SECONDLY, THAT these atmospheres consist of the same fluid with the atmosphere of the earth, viz. Air.

THIRDLY, THAT they are mutually repellent to each other ; as the globes they surround are in a state of mutual attraction or gravitation.

I. As the proof of the existence of the atmospheres of the Sun, Planets and Comets depends upon a variety of astronomical observations, it is necessary to be particular as to each of them.

AND, I. That the *Earth* we inhabit (which is a Planet vastly inferior, both in bulk and situation, to some others) has one, we have the best evidence possible, viz. the testimony of our senses ; besides, we all know, that the air, which every where surrounds the Earth, is essential to the breath of life.

2. THAT *Mars* has an atmosphere, and that very extensive, has been demonstrated from the occultation of a fixed Star by that Planet * ; as the Star vanished at a distance from, or without ever arriving at a visible contact with his limb ; as was observed by *Cassini*, October 1st, 1662. The like was observed after the same occultation, by M. *Roemer*, at Rome, the Star not being visible after the transit till at a distance from his limb.

3. *JUPITER*'s belts are in a fluctuating state, as they frequently vary their form, size, and situation ; † which cannot be accounted for, unless we suppose them

to

* See Smith's Opticks, Vol. II, Page 430.

† Idem, Page 433.-

to be clouds and exhalations, floating in an atmosphere which furrounds his globe. †

4. SOME belt-like appearances were discovered in *Saturn* by Mr. *Hadley* through his five-foot reflector, and by Mr. *Pound* through *Hugenius's* glass, though they appeared very faint, as he is so remote ‡; which belts are probably in the same fluctuating state as those of *Jupiter*, and arise from similar causes.

5. THAT *Venus* has an atmosphere may also be inferred from the variable spots which have been observed upon the face of that Planet, § which are probably of the same kind with the belts of *Jupiter*, or the clouds which float in our own atmosphere, and, consequently, have a similar one to sustain them †. But for proof of its existence we need go no further back than the late transit of *Venus* over the Sun's disc, anno 1769; when the atmosphere itself was visible, and that in different situations, to observers in distant parts. *

6. *MERCURY* is too near the Sun to favour us with such observations; but if we suppose his globe inhabited, he doubtless stands as much in need of an atmosphere as any other Planet, and has as important purposes to be served thereby.

7. THAT

† Sir Isaac Newton says these belts "are formed in the clouds of that Planet." Princip. Book III. Lemma Prop. XXXIX.

‡ S. Opt. Page 441. || Idem, Page 421.

§ Were these belts, spots, &c. really adhering to, and parts of their respective globes, they would always appear invariably the same, in the same situations, as those of the Moon do; in which no atmosphere has yet been discovered.

* See Transactions of the American Philosophical Society of Philadelphia, Page 42. Also Observations by Mr. Benjamin West at Providence, N. E. Page 16.

7. THAT the Comets are surrounded with atmospheres is already taken for granted, because self-evident. Sir *I. Newton*, from various observations, concludes that their diameters are, one with another, at least equal to ten diameters of their nuclei or solid globes. †

8. THAT the Sun has an atmosphere, and that proportioned to his amazing magnitude, is rendered highly probable by the macular appearances, or spots frequently discovered upon his disc : Which, as they often suddenly break out, and as suddenly disappear, and sometimes vary their shapes, even when under the eye of the observer ; can be no other than huge clouds of smoke, or other vapours floating in such atmosphere ; huge indeed ! as they frequently exceed the whole superficies of the Earth. Mr. *Derham*, who was peculiarly assiduous in observing them, has assigned a cause, to which their phænomena accurately agree. He supposes them to be immense volumes of smoke, belched forth by volcanoes or fiery eruptions, which are frequently breaking out upon his surface ‡. These spots, when large, sometimes continue during a whole revolution of the Sun round his axis, or about twenty-five days ; and it is from the regular returns of such spots to the same part of his disc again that this revolution has been determined. But such clouds, were they not supported by an atmosphere, would tumble down again upon the Sun presently after the explosions which raised them were over,

† See Princip. Book III. Prop. XLI.

‡ See Jones's Abridgment of Philosoph. Transf. Vol. IV. Page 238.

over, as we see vapors emitted in an exhausted receiver, for want of air to sustain them, sink down to the bottom of the receiver.

II. We shall now endeavour to prove that the planetary, cometary, and solar atmospheres, consist of the same elementary fluid with the atmosphere of the Earth, viz. *AIR*.

AIR is a fluid, which when pure is transparent, and in the highest degree elastic, being indefinitely compressible and dilatable; which qualities are truly characteristic of it, as we know of no other fluid to which they belong.

It may be necessary to observe here, that upon our globe, which (as already observed) is itself a Planet, the presence of air is necessary, both to the preservation of animal life, and to the existence of flame: For in a glass receiver, small animals die, and candles go out, immediately upon the air being exhausted; upon air also seems to depend the explosive power of enkindled vapors; for gun-powder itself, one of the most powerful agents hitherto invented by the art of man, if fired by an hot Iron in vacuo, will consume away, but never flash, nor explode; and it is generally agreed by those who are acquainted with experimental philosophy, that this vivifying, inflaming quality of air, depends upon its elasticity, or the active, contrifugal power of its particles, to be considered under the next general head. This being premised, we proceed to prove,

First, THAT the atmospheres of the several globes
of

of the System consist of transparent fluids : The truth of which will be sufficiently evident, if we consider the several phænomena by which they were discovered.

It has already been shewn that Mars is surrounded with a very extensive atmosphere ; which, had it not been transparent, must have escaped the notice of astronomers during the time of the occultation of the star before mentioned ; for were it opaque, it would, by reflecting the Sun's rays, as well as by its want of transparency, have hid the Planet itself, and by the observers have been confounded with it † ; in which case the moments of the occultation of the star, and of its visible contact with the limb of the Planet, would have been the same ; whereas the disappearance of the star before any such contact could take place, is a demonstration of the refraction of its rays in a transparent medium, with which the Planet is surrounded.

THE changes which are observable in those fluctuating collections of heterogeneous matter, of which the belts and spots in the other Planets, and the Sun consist, for the same reason, could never have been discovered, were they not sustained in transparent fluids, above the surfaces of their respective globes.

THE transparency of the cometic atmospheres is undeniable, as their nuclei are frequently seen thro' them, although they occupy spaces equal to many diameters of the Earth ; and the smallest stars are visible through the

† In like manner, as Sir I. Newton concludes, (Prin. B. III. Lemma IV.) " that
" the Earth, if it was viewed from the Planets, would without all doubt shine
" by the light of its Clouds."

the tails which proceed from, and are only expansions of them ; in which tails we have ocular demonstration of a most surprizing dilatibility ; from whence their recompressibility and elasticity may be justly inferred.

Secondly, ALTHOUGH there are no observations in the records of astronomy which prove this elasticity in the planetary atmospheres ; yet, as the Planets are with the highest reason supposed to be inhabited Worlds, the presumption is at least very strong, if short of a demonstration, that their atmospheres are designed to answer purposes every way similar to those which are effected by the atmosphere of the Earth, and that they are endued with all those properties, which are, with us, necessary to the preservation of animal Life ; consequently that they are elastic, as well as transparent, and altogether like our air.

THE atmosphere of the Sun is, by his excessive lustre, hid from our view ; but if we consider him as an immense flaming globe, kindled up to warm and enlighten the whole system, we may well suppose that he has a large share of that fluid, without which (as before observed) scarcely any flame can subsist with us for a moment. Some Authors indeed are of opinion, and not without reason, that the Sun is not a body of fire, as commonly supposed ; Doctor *Knight* in particular, in his curious treatise of attraction and repulsion, as two universal principles, by which he endeavours to solve all the phænomena in nature, seems to be of opinion, that the inhabitants of the Sun (if inhabited) are in as much danger of

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suffering

suffering from cold, as from excessive heat *. But of whatever substance the body of the Sun may consist, Mr. Derham has, by his observations, put it beyond all reasonable doubt, that the *maculae* and *faculae*, or the darker and brighter spots observable at times upon the Sun's disc, are really owing to the bursting of volcanoes; "the *faculae* being only the appearance of the flames, after the dense smoke attending the explosions is dissipated, or removed to a distance from them †." Now there is no reason to doubt but that, upon our globe, air is as necessary to the flames of *Ætna* and the eruptions of *Vesuvius*, as to the smaller blaze of a candle, or to the explosion of gunpowder; may we not then rationally conclude, that it is equally necessary to those astonishing volcanoes in the Sun?

It is now proved, as far as the proposition is in the nature of it capable of proof, that the celestial bodies are surrounded with atmospheres, and that these atmospheres consist of transparent elastic fluids, like the air surrounding this Earth. It remains that we prove,

* See said treatise, Page 38; in which are these remarkable Words: Speaking of the Sun and fixed Stars, he says, "Their Globes are no longer frightful Gulphs of Fire, but inhabitable Worlds: Those Philosophers who thought them too hot for the Habitation of Salamanders, and those sublimer Genii, who thought them to be Hells, will now perhaps be in Pain, lest the Inhabitants should freeze with Cold".----- However, Doctor Knight concludes from his own principles, that the Sun has an immense aerial atmosphere condensed round him; for in the preceding Page 57, he says, "The vast Weight of the Sun's Atmosphere must make the Density of the Air so great near the Sun's Surface, that what would create a Sound scarce audible with us, would there produce a very loud Noise."

† See Jones's Abridgment of Phil. Transl. before cited.

III. THAT

III. THAT the atmospheres of the Sun, Planets, and Comets are mutually repellent to each other ; as the solid globes they surround are in a state of mutual attraction or gravitation.

It must here be observed ; that in reasoning upon gravitation, the great Author of the present philosophical system of the Heavens argues downward from the greater to the lesser, from *Worlds* to *Atoms* ; thus, finding by mathematical deductions, compared with astronomical observations, that all the globes of the solar System, Sun, Planets and Comets gravitate, or have a mutual tendency towards each other, and that this reciprocal attraction is proportional to the quantities of solid matter they respectively contain ; he very justly concludes, that every single particle in any one of their solid masses both attracts, and is attracted by, every other particle of matter, contained in every globe throughout the solar System.*

BUT as the Heavens exhibit no phaenomena from which we can, directly and with equal certainty, infer the existence and universal extent of the contrary principle of repulsion, as subsisting between the atmospheres of the heavenly bodies ; we are here obliged to use a contrary method, and to reason upward from the powers and properties which, by their effects, we discover to belong to those parcels of air upon which we can make experiments ; to the effects, which the same powers and properties would naturally produce, in those vast collections of air, which con-

* *Principia Sparsim.*

stitute the atmospheres of the several globes ; and if by tracing the necessary operations of these powers, step by step, we can at length arrive at any of the grand phænomena of nature, we may with the highest reason conclude, that these phænomena are the effects of those powers.

WE shall therefore endeavour to prove from authors of the best credit, or from experiments which any one may try at his leisure,

1. THAT there is a mutual repellency subsisting between the particles of air, whereby they continually endeavour to recede from each other ; in consequence of which, that fluid is indefinitely dilatable from the centrifugal activity of its particles, as well as compressible by any foreign power.

THE honourable *Robert Boyle*, Esq; found by experiments, that air might be so rarefied as to occupy 13769 times the space it fills when in its natural state near the surface of the Earth † ; other experiments prove, that it may be so condensed, as to be contained in $\frac{1}{60}$ part of the same space*, therefore multiplying 13769 by 60, it appears, that the cubic space it is capable of filling, under different circumstances, may be as 826140 to 1. But the cube root of 826140 is 94 nearly ; therefore the central distances of the particles from each other, as discoverable by actual experiment, may be as one to ninety-four, and that from their centrifugal activity.

† See Shaw's Abridgment of Boyle, Vol. I. Page 551.

* See Martin's Philosophical Grammar; Page 178.

MOREOVER

MOREOVER, Sir *I. Newton* from experiments concludes this repulsive power to be so great, as that a cubic inch of air, condensed as it is with us, if removed one semidiameter of the Earth above its surface, where it would be free from the pressure of an incumbent atmosphere, would so expand itself by virtue of this power, as to fill the whole sphere of Saturn's orbit; nay he adds, "and far beyond it" †.

2. THIS mutual repellency of the particles of air is greatly increased by heat. For if a bladder not more than half filled with air, be tied up tight, and laid before the fire, the additional expansive power, which the air contained therein acquires from the heat, will swell the bladder to its utmost extent, and will at length burst it with an explosion.

3. THE particles of air, although mutually repellent amongst themselves, are with regard to other matter, in the common state of gravitation or attraction. This is evident from their being condensed in the form of atmospheres round the solid globes of the System, and attending them through all their revolutions.

4. THE mutual repellency of the particles of air is indefinitely greater, in proportion to the quantities of repelling matter, than the mutual attraction, subsisting betwixt the solid particles of attracting matter.

THE truth of this proposition will appear, at least highly probable, if we consider that the quantity of

† Princip. Book III. under Prop. XLI.

matter contained in our air near the surface of the Earth, and which gravitates in common with other matter towards its center, is so small, tho' condensed by the incumbent weight of the whole atmosphere, that one quart of it weighs no more than eight grains, as appears from experiments ; yet so great is the repulsive power of its particles, that a small quantity of it, condensed by art in the barrel of an air-gun, of the size and bore of a common fowling-piece, is sufficient, when permitted suddenly to expand itself through the tube, to discharge a musket ball, in the same manner as fired gun-powder, the noise excepted, and with the like fatal effects.

We shall now proceed to prove the following proposition, viz. If two corpuscles of matter be in a state of mutual repulsion at any given distance, as *A. B.* Fig. 1. where they repel each other with a given force, say $= 1$. and this repulsion decreases, either as the distances *Ac*, *Ad*, *Ae*, *Af*, &c. or as the squares, cubes, or any higher powers of those distances, increase, the extent of that repulsion is indefinite.

For suppose *A* and *B* to be two such particles repelling each other at the distance *AB* with a force $= 1$. continue the line *AB* indefinitely through the equidistant points *c*, *d*, *e*, &c. let the particle *A* be fixed, *B* movable : Let us suppose this power to decrease, 1st, simply, as the distances increase ; then, if we suppose the particle *B* to move successively through *c*, *d*, *e*, &c. this power, at those several distances, will be
as

as follows, viz. at $c = \frac{1}{2}$, at $d = \frac{1}{3}$, at $e = \frac{1}{4}$, &c. in infinit.

2. If it decrease
as the squares } $c = \frac{1}{4}$, at $d = \frac{1}{9}$, at $e = \frac{1}{16}$, &c. in inf.
increase, it is at

3. If as the cubes, } $c = \frac{1}{8}$, at $d = \frac{1}{27}$, at $e = \frac{1}{64}$, &c. in inf.
it is at - -

4. If as the biqua- } $c = \frac{1}{16}$, at $d = \frac{1}{81}$, at $e = \frac{1}{256}$, &c. in inf.
drates, it is at

&c. onwards indefinitely.

Now whatever the distance assigned between the two particles may be, and whatever may be the index of the power which expresses the ratio of the decrease of their repulsive force, this force will in every case be expressible by a fraction whose numerator is 1, and its denominator equal to the given distance, involved according to the index of the given power, as is evident from inspection of the foregoing fractions as they stand. It can never, therefore, become equal to nothing, until the denominator of the fraction becomes infinite, which never can be at any assignable distance, however great; therefore, the extent of this mutual repulsion is indefinite. Q. E. D.

In mathematical reasoning, the smallest quantities are not to be disregarded, unless supposed smaller than any assignable, as in fluxions, &c.; for, as all the huge masses of the solar System, are composed of particles of matter inconceivably small, so their mechanical effects upon each other are proportional to the numbers of such component particles they respectively contain; and though the mutual effects of
two

two single particles, at any given distance, might be indefinitely small, yet we may easily conceive, that, when indefinite numbers of such particles are consolidated into one mass, and exert their influence from a common center, that *that influence* may be as extensive as the solar System, and perhaps as the material universe. Thus the Sun, by the united attractive force of his constituent particles, regulates the motions of the Comets, even at their aphelia, where their distances from him confound the human imagination; amounting in some of them to many thousands of millions of miles; yet, at those amazing distances from the Sun, they are by his influence retained in their proper orbits, without any deviation, till at length they are brought back to him again, many of them after excursions of some hundreds, and possibly some of them after thousands of years; in effecting which every particle of matter in the Sun, however small, bears a part.

ON the other hand, the atmospheres of the heavenly bodies consist of particles mutually repellent; not consolidated indeed, as that would be incompatible with the nature of the fluid composed of them, but each, in consequence of the mutual attraction between its constituent particles and the globe it surrounds, condensed into a fluid mass.

IN this case also, though the mutual repellency between two single particles might at a given distance be indefinitely small, yet the influence of two such masses upon each other, when thus condensed, may
be

pellency by any experiments we can make ; and if to other experiments we add Sir *Isaac Newton's* reasoning from some of his own, we must conclude them indefinitely so, and consequently that their repulsive force decreases regularly according to some certain ratio of the increase of their distances, viz. either as the *distances simply*, or as their *squares, cubes, or some other powers* thereof.

It seems most agreeable to mathematical reasoning, to suppose, that all powers, whether attractive or repellent, which act in right lines, to, or from the centers of the attracting or repelling bodies, are proportioned to the inverse ratio of the *squares* of the distances of their centers. For, if we consider these powers as represented by lines, or rays, converging from every point of the visible concave of the Heavens to a given point as a center in case of attraction, and diverging equally from said center in case of repulsion ; and suppose a corpuscle of matter to be placed in any part of that space, the number of such rays, intercepted by, and falling upon said corpuscle, whether they were converging or diverging, would be *in that ratio, viz. inversely as the squares* of the distances of said corpuscle from such central point. The truth of this assertion is capable of the most simple mathematical demonstration ; which may be here omitted, as it has been already sufficiently demonstrated by others : Upon it indeed depends the truth of Sir *I. Newton's* position, viz. that “ the density of the Sun’s
“ rays is reciprocally as the *squares* of the distances
“ from the Sun ” ; from whence he deduces the proportions of light and heat, enjoyed by the several Planets of the System.

If we conceive such supposed rays to move with a uniform velocity, and to be attended with any momentum whatever, whereby, when converging, they impel the corpuscle to, or repel it, when diverging, from said central point ; as the whole momentum would be proportional to the number of the intercepted rays, the tendency of the corpuscle to, or from the center, that is, its attraction or repulsion would also be in the aforesaid ratio. That the attraction of gravitation is regulated by this law, astronomical observations sufficiently demonstrate.

BUT Sir *I. Newton* concludes from experiments, to which all theoretic opinions must ever give way, that the mutual repellency* between the particles of air is reciprocally as their distances only, or "nearly so."*

If this be the case, the physical effects of two particles, and consequently of two fluid masses composed of such particles, upon each other, must be yet vastly greater than if it were reciprocally as the *squares* of the distances, as we before supposed, as will evidently appear upon inspection of the following scheme ; in which the *first* series represents the distances, increasing in arithmetical progression ; the *second*, the repellent force, decreasing as the distances increase only ; the *third*, the same force considered as decreasing according to the increase of the *squares* of the distances ; thus :

	<i>A B</i>									
Distances — —	⊙	1	2	3	4	5	6	7	8	} &c.
Inverse ratio of dist. ⊙	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$		
--of the squares of dist. ⊙	1	$\frac{1}{4}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{25}$	$\frac{1}{36}$	$\frac{1}{49}$	$\frac{1}{64}$		

* Newt. Princip. Book II. Prop. XXIII.

HERE

HERE it is evident that at the distance $3 AB$, if the repellency decreased only as the distances increase, that that force would be equal to $\frac{1}{3}$; but if it decreased as the *squares* of the distances increase, it would at the same distance be equal only to $\frac{1}{9}$; at the distance $5 AB$, in the former case, it would be $\frac{1}{5}$, in the latter $\frac{1}{25}$; if at the distance $8 AB$, in the former it would be $\frac{1}{8}$, in the latter $\frac{1}{64}$, &c. But 3 is the square-root of 9 or $\frac{1}{9}$ of $\frac{1}{9}$, $\frac{1}{3}$ of $\frac{1}{25}$, and $\frac{1}{8}$ of $\frac{1}{64}$, &c.

It therefore follows, that if this repellent force does actually decrease simply as the distances increase, the quantity of it at any given distance is greater, in the direct ratio of that distance, than if it decreased in the ratio of the *squares* of the distances; consequently, the sensible effects of two such fluid masses, condensed, as we have already supposed, round the particles A and B , would be proportionably more extensive.

Now, what are the atmospheres of the Sun, Planets and Comets, but vast collections of these repellent particles of air, condensed round their respective globes, by the mutual gravitation subsisting between them, in like manner as we have already supposed them to be condensed round the corpuscles A and B (Fig. 1.)? But if, according to Sir I. Newton, so small a quantity as a cubic inch of our air, if left to itself at the height only of one semidiameter of the Earth, might exert this force, so as to fill the whole sphere of Saturn's orbit; it demonstrably follows, that the atmospheres aforesaid, which consist of huge masses of the same fluid, may extend their influences as far

at least ; and though the condensation of each round its own globe, by virtue of their mutual gravitation, would prevent the scattering of its component particles, and confounding itself with the atmospheres of the neighbouring Planets (as would undoubtedly be the case, however great their distances might be, did the cause of that condensation cease) yet it is by no means impossible, nor yet improbable, that under some circumstances, the physical effects of two such atmospheres upon each other may become very apparent : For if we suppose two equal Planets with their atmospheres (as *A* and *B* Fig. 2.) to pass near to each other, these atmospheres being fluid, and that in the highest conceivable degree of fluidity, would give way to the least degree of external force, and in consequence of their mutual repulsion would recede from each other ; but the attractions of their respective globes would prevent their leaving them wholly, while each would so far retire, as to be depressed in the parts next the other, and to swell out in the opposite parts, changing their spherical figures to two oblong spheroids as at *C* and *D* (Fig 2.) But this is said upon the supposition that both the globes and their atmospheres are equal, each to the other respectively. Whereas, if we suppose the body *A* to be an immense globe like the Sun, having an atmosphere proportionably large, * and consequently

* The solar atmosphere is dense enough at the height of seven or eight thousand miles, or 1-137th part of the Sun's diameter above his surface, to sustain those huge clouds of smoke which appear to us like spots upon his disc. See Mr. Professor *Winthrop's Cogitata de Cometis*, Page 25. If therefore the atmosphere of the Sun consists of air, as we have endeavoured to prove it does, and the solar clouds and vapors are similar to our own, and, like them, require a certain density of air to sustain them in equilibrio, it follows, that the density of the air in the Sun's atmosphere is as great at the height of 7000 miles above

consequently containing many thousands, and perhaps some millions of times the quantity of this repellent fluid contained in the atmosphere of *B* ; which we may now consider as a Comet, of equal magnitude with the Earth, but surrounded, like other Planets of the same species, with an atmosphere of great extent, when compared with the magnitude of the globe itself ; and if we suppose also the visible effects of the mutual repellency of these atmospheres to be reciprocally as the quantities of the repellent fluid contained in them, the atmosphere of the Comet might be prodigiously lengthened when in the neighbourhood of the Sun, and repelled to great distances behind the nucleus, while at the same time, the natural spherical form of the Sun's atmosphere would not be sensibly disturbed by that of the Comet. This reasoning may be illustrated by considering the effects of the contrary principle of mutual attraction or gravitation subsisting between the globes themselves, which effects are subjects, both of mathematical computation, and of astronomical observation : For it is very certain that Comets perform their revolutions round the Sun, in consequence of this mutual gravitation, in orbits very eccentric, and nearly parabolical ; whereas it is probable, that the joint efforts of all the Comets which ever appeared, would scarcely disturb the repose of the Sun in the center of the System.

A Comet, in its descent through the planetary orbs, approaches the Sun with an accelerating velocity, un-

above his surface, as that of our own air, at the height of but 3 or 4 miles above the surface of the Earth ; a height which our clouds, probably, never exceed. How vast then must be the extent of the Sun's whole atmosphere !

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til it arrives at its perihelion ; entering deeper and deeper within the spheres, both of the repulsion of the Sun's atmosphere, and of the activity of his rays ; in consequence whereof the cometic atmosphere is continually rarefying during this descent, both from the expansion it undergoes, by means of that repulsion, and from the increasing heat, which it acquires, as it approaches the Sun, which heat, as already observed, contributes greatly to the repellency of the particles of the *âërial* fluid. By the concurrence of these causes, if admitted, a tail must necessarily be formed, the length of which would depend, partly upon the quantity of air contained in the cometic atmosphere, and partly upon its proximity to that of the Sun, and consequently would increase until the Comet arrived at its perihelion, or rather, from the continuance of the causes, until a few days after, which is most agreeable to observation. When a Comet is at this stage of its revolution, if it pass near the Sun, the tail usually extends from its head through vast regions of space, exhibiting a curious spectacle to distant Worlds.

If a cometic atmosphere consisted of an *unelastic* fluid, and were thus repelled by the atmosphere of the Sun, it would put on the form of a very oblong spheroid, both ends of which would be terminated by a regular curvilinear surface as at *A* and *a* (Fig. 3) ; but as it is an elastic fluid, whose constituent particles are, amongst themselves, mutually repellent, as soon as ever the attraction of the nucleus, which before condensed them spherically round itself, is diminished in *any* part of that atmosphere, by this opposite repulsion, the particles

in that part become more and more at liberty to exert their own inherent repellency, which they would at length do *quaquaversum*, were it not that the repellent power of the Sun's whole atmosphere, so far predominates over their own mutual repellency, as constantly to keep them in a direction nearly opposite to the Sun's center; but as this is not sufficient totally to prevent a lateral dilatation, the tail grows broader and broader, as it extends from the nucleus, while the longitudinal expansion is rather increased than impeded thereby, until the whole train, in a fair view of it, wears nearly the form of a parabolic curve; the several parts of which are less and less distinct, as they are further distant from the head, until at length, spectators shall, at the same time, differ ten or twenty degrees in their estimation of its apparent length, according to the different acuteness of their sight. * (See Fig. 4. *B b.*)

AFTER the perihelion, as the Comet recedes from the Sun, the mutual repulsion of the two atmospheres gradually decreases, while the mutual gravitation of the Comet and its own atmosphere proportionably gets the better of it, until at length the exiled atoms are drawn home, and that perhaps without the loss of a single one; unless the tail should happen to sweep the sphere of some Planet in its way; in which case, if the atmosphere of the Planet were large, the mutual repellency of the two would rather occasion a bifurcation of the cometic atmosphere than a union or con-

* Sir I. Newton in his Princip. says, "the Comet of 1680, in the month of December, emitted a notable tail, extending to the length of 40° , 50° , 60° or 70° and upwards": The disjunctive (*or*) intimates an uncertainty, of at least 30 degrees, in its apparent length.

fusion

fusion of them; but were that of the Planet very small, and did we suppose that in consequence thereof, that of the Comet might leave a small portion of its tail behind; still no detriment to us could reasonably be expected or feared, upon that account, considering the amazing rarity of the Comet's Tail. The cometic atmosphere being gradually re-condensed round its nucleus as before, would provide it with a suitable garment for winter quarters in the remote parts of its orbit; agreeable to the ingenious hypothesis of Doctor *Williamson*.

THE thickness of a Comet's tail, or the diameter of a section made perpendicularly thro' it, is amazingly great towards its extremity; the apparent breadth of the tail of the Comet of 1680, where its distance from the Earth was equal to the distance of the Earth from the Sun, was equal to above three apparent diameters of the Sun*; consequently the real thickness of that part of the tail was about three millions of miles, or between three and four hundred diameters of the Earth, yet, says Sir *I. Newton*, "the smallest Stars were visible through it without any diminution of their lustre." How inconceivably rare then must it have been! Perhaps for some thousands, not to say millions of miles, reckoned from its extremity towards its head, it might not have contained more air than a well blown bladder does with us: And that this is not only possible, but even probable, appears from Sir *I. Newton's* computation of the expansion which a cubic inch

* The Author remembers to have met with this Observation somewhere, but cannot at present recollect where. But it was not far from the truth, if applied to the Comet of 1769.

of our air is capable of, already repeatedly referred to.

So much for the third general proposition, which the reader will receive or reject, according to the weight of the evidence offered in support of it. It is however hoped that candor will be exercised, and that the whole will not be exploded, merely, for want of accuracy in the method, or of perspicuity in handling a subject so difficult of access.

A short digression here may not be amiss, in order to prevent the uncomfortable impressions, which the appearance of a Comet is apt to make upon the minds of some, and which were greatly increased during the appearance of the Comet of 1769, by an injudicious publication in one of the southern newspapers, wherein it was insinuated, that if that Comet should pass between the Earth and the Sun, the Earth would pass through the tail of the Comet; the consequence of which, the writer supposed, might be fatal even to the World itself. But from the foregoing observations it is evident, that such apprehensions were groundless. The ingenious and learned Mr. *Whiston* has indeed endeavoured to prove, in order to support his *Theory*, that a Comet passing near the Earth in its descent towards the Sun, occasioned the universal deluge, by leaving behind it a sufficient quantity of vapors from its atmosphere and tail, (in which he supposed the Earth to be enveloped,) when condensed into rain, to drown the World. He further supposed that a Comet, in its ascent from the Sun, might be sufficiently heated to cause a general Conflagration, should it find the Earth in the same situation.

situation. In consequence of which the fears of many are usually alarmed, at the appearance of a Comet, by the apprehension of some grand catastrophe. But if the tails of Comets are so extremely rare, as we find they must necessarily be, and as every one must be convinced they are, who ever saw the Stars shining through them; how can we conceive that the Earth in passing through one of them, could carry off *oceans* sufficient to submerge "*all the high hills under the whole Heaven*"? to effect which, many of *our* oceans would, doubtless, be necessary. On the contrary, it seems probable, from the foregoing considerations, that the tails of all the Comets which ever appeared, could not, jointly, furnish water sufficient for one *ocean* only.— If so, the near approach of a Comet must be found utterly insufficient to account for the superior waters of the deluge, or the forty days rain mentioned by *Moses*; whatever disorders might otherwise be occasioned in both globes, by their mutual gravitation, in such vicinity. And had the Earth passed directly through the midst of the tail of the Comet of 1769, or of any other, it is not in the least probable, unless the Comet had come near enough to injure us upon other accounts, that the Earth could have carried off with it, or that the Comet would have imparted to us, vapors sufficient, even for a common thunder-shower. But this is submitted to the reader; who, perhaps, upon the perusal of the second part of this essay, may be of opinion, that a Comet, in its ascent from the Sun, is no more calculated to set the World on fire, than to drown it in its descent. But to return to our subject.

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HERE a material objection may naturally arise, viz. why should the Comets appear with tails, and those, generally, of enormous lengths, while the Planets, which have atmospheres as well as the Comets, are always seen without them, even when at equal distances from the Sun?

To this it may be answered ; that the atmospheres of the Planets are so small, in proportion to the globes they surround, compared with those of Comets, that whatever may be the cause of the tails of the latter ; if the same cause act upon their several atmospheres, proportionably to the spaces they respectively occupy, the tails of Comets may appear of astonishing lengths, while those of the Planets shall be totally insensible. In other words ; the Planets in similar situations shall have no tails at all.

THE Earth, as has been repeatedly observed, is a Planet, with which, as it is the place of our abode, we are well acquainted : The height of its atmosphere is generally computed at about fifty miles ; beyond which, its density is not sufficient to reflect the rays of the Sun in the crepusculum or twilight : The diameter of the Earth is about 8000 miles, the diameter then of the Earth and atmosphere together is about 8100 miles ; from whence it appears by computation, that the space occupied by the atmosphere alone is to the space occupied by the Earth alone, as 1 to 26 nearly.

THE diameter of the atmosphere of a Comet, as before observed, is, at a medium, equal to ten times the

the diameter of its nucleus; and, spheres being as the cubes of their diameters, the magnitude of a Comet and its atmosphere together is equal to one thousand times the magnitude of the Comet alone; consequently, the space occupied by the atmosphere, is to the space occupied by the nucleus as 999 to 1.

LET us suppose a Comet of equal bigness with the Earth, having an atmosphere as above described, to be so situated, as that the Sun, the Earth and the Comet, may be in the Angles of an equilateral triangle: Let us suppose also the visible effect of the repelling power of the Sun's atmosphere upon those of the Earth and the Comet, to be in proportion to the spaces they respectively occupy: The magnitudes of these atmospheres being one to the other as 999 to $\frac{1}{1000}$, that is as 25974 to 1; when a spectator upon the Earth might see the tail of the Comet extend through an arch in the Heavens of 60° ; had the atmosphere of the Earth a tail, arising from the same cause, in proportion to the space it occupied, to a spectator upon the Comet it would subtend an angle of no more than $0^\circ 0' 8'' 81'''$ or 60° divided by 25974, an angle which the best instruments could never discover in an object so dubiously defined: In other words, when the Comet would have a tail 60° in length, a Planet at the same distance from the Sun would have none at all.

THE atmospheres of the inferior Planets are probably less in proportion, and those of the superior, larger than that of the Earth. But this subject may
more

more properly be introduced in the second part of this Essay.

The principle of repulsion by which we have endeavoured to account for the tails of Comets, and their opposition to the Sun, may receive further confirmation by considering some of the phænomena which the atmosphere of a Comet would exhibit in the neighbourhood of the Sun, were the Sun divested of his atmosphere, or were his atmosphere deprived of its repellent principle : We shall therefore endeavour to prove the following proposition, *viz.*

WERE the Sun without an atmosphere, or some other appendage in its nature repellent to the atmospheres of Comets, and the æthereal spaces void of resistance ; instead of *one* tail, and that always turned from the Sun, every Comet would have *two* ; the direction of one being *towards*, the other *from* the Sun, of which the former would be the most considerable, and both would increase as the Comet approached the Sun, from the increasing gravitation towards him.

FOR though a Comet's atmosphere in its natural state surrounds the nucleus in a spherical form, (a form that all fluids which tend to a common center of gravity must put on) yet if we suppose this atmosphere to be affected by its gravitation towards the Sun, and to consist of an unelastic fluid, like water ; those parts of this fluid which were nearest to, and most remote from the Sun, would have their gravitation towards the center of the Comet lessened by the Sun's

Sun's attraction, and thereby, from a spherical form the whole would be changed to an oblong spheroid. This is in fact the case with our ocean, which is changed from a sphere to a spheroid by the gravitation of the Moon ; the axis of which spheroid, revolving round the axis of the Earth in consequence of the diurnal motion, causes the flux and reflux of our sea. But the atmosphere of a Comet is indefinitely elastic, and thence capable of an unlimited expansion ; therefore, in proportion as it is in any part elevated above the superficies of the sphere it occupies when in its natural quiescent state, such parts are proportionably at liberty to expand themselves, by virtue of the mutual repulsion of their component particles, which are now in great measure freed from that constraint which before condensed them ; * which would change both ends of the spheroidal figure, to forms similar to the tails which commonly attend the Comets, being broader as they become rarer towards their extremities, on one side and the other : But the tail next the Sun would be the most considerable, the effects of his attraction on that side being greatest ; and, should the Comet approach near enough to the Sun, a continued aerial stream would be formed from one globe to the other, whereby the Sun, by his superior attractive power, would by degrees rob the Comet of its atmosphere, condensing the same round his own globe, without leaving the Comet a sufficiency for the purposes of life and vegetation in its solitary retreat without the planetary spheres. But as the Sun has an atmosphere, repellent to the atmospheres of the other heavenly bodies, these in-

* See Page 31.

conveniences

conveniences are thereby prevented, and every globe of the system retains its own, unimpaired, through every stage of its revolution.

THAT the projection of the tail of a Comet from its nucleus, and its perpetual opposition to the Sun, do arise from the mutual repellency of the atmospheres of Sun and Comet, as we have endeavoured to prove in the foregoing pages; may be confirmed and illustrated, if not demonstrated by electrical experiments.

THE electric fluid is an element, as distinct from all others which we are acquainted with, as air is from water; and if there be any such thing existing in nature, as pure elementary fire, this claims that character, in preference to all others. For fire, in its common form, is so far from being a pure element, of itself, that the presence of air is necessary to its very being. Whereas the electric fire, in many experiments, acts with greater freedom *in vacuo*, than in the open air. But, different as this wonderful substance is from all others, we find, that some of its properties greatly resemble those of air, already treated of: And, if the following propositions, which are introduced to prove that resemblance, can be confirmed by experiments; and it be allowed, that similar causes, naturally, produce similar effects; it is presumed, that the solutions of the cometic phenomena, offered in this essay, when composed with those experiments, will be found not inadequate to the phenomena.

Prop. I. THERE is a mutual attraction, subsisting betwixt the electric fluid and common matter; in consequence

consequence of which, the former is capable of, and liable to a condensation round the latter; in the same manner as air, by common gravitation, is condensed round the heavenly bodies, in the form of atmospheres.

THE truth of this proposition has been abundantly proved by Doctor *Franklin*, and other writers upon this subject: Indeed, the success of all our electrical experiments depends upon this property: We may add further, that all the phænomena which have ever been observed, in which that element is concerned, from the attraction of small hairs, dust, &c. in consequence of the attrition of amber, to the most severe blaze and irresistible force of lightning; depend in a great measure, upon the same property.

Prop. 2. AIR, as we have seen, is a fluid, the particles of which mutually repel each other: So, also, is the electric element.

THE truth of this proposition is demonstrated by the following

EXPERIMENT. I.

SUSPEND a plate of metal, by wire, from the prime-conductor generally used in these experiments, and electrify it. On another plate, placed under the former, at the distance of three or four inches, put a small quantity of dry sand, meal, bran, flour, or even the most impalpable powder; the particles upon the lower plate, being attracted by, and themselves attracting the electric atmosphere, condensed round the

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under

under surface of the upper plate, a beautiful shower will ensue : These particles will ascend to the upper plate ; each, by virtue of the aforesaid attraction, will receive, and condense round itself, in the form of an atmosphere, a quantity of this fluid proportional to its capacity ; be immediately repelled from it, and descend towards the lower plate : But these corpuscles descend, diverging from each other, many of them falling wide of the plate, upon the table beneath, to return no more : Which divergency, not only indicates, but is the necessary consequence of, the mutual repellency of the electric atmospheres, now condensed round them. Those that recover the lower plate, having discharged their fire, re-ascend together with those that were left behind at first ; with them receive a new charge, and return diverging, as before. This operation continues, until most of the particles are scattered on the table below, few being left between the two plates. Now, as the quantity of the fluid condensed round each corpuscle is, probably, proportional to the superficies of the corpuscle ; * and as this experiment will succeed with an impalpable powder, if perfectly dry, we may conclude, that the smallest conceivable portions of the electric matter, when once severed, are mutually repellent ; from whence we may infer the repellency of its constituent particles themselves.

THIS property is also largely treated of by Doctor

* See Doctor *Franklin's* printed letters page 55. § 13. wherein he asserts, that
 “ The form of the electrical atmosphere is that of the body it surrounds.”---
 This he proves by experiments, and from this principle has given a probable solution of the operation of points, at a distance from the electrified bodies,

Franklin,

Franklin, * and is as necessary to most electrical experiments, as the former is to all ; and, doubtless, contributes one half to the amazing rapidity of lightning, to which nothing, short of that of the rays of light, can be compared.

Prop. 3. When two small spherical bodies have electrical atmospheres, condensed round them ; those atmospheres are mutually repellent : As we have endeavoured to prove, from the known mutual repellency of the particles of air, that the atmospheres of the heavenly bodies are, amongst themselves.

THIS proposition naturally results from the last, and is, in some measure, involved in it ; but, as the experiments now to be produced in support of it, may shew us in what manner the electric atmospheres act upon, and affect each other, it deserves a more particular consideration. For, as these atmospheres are invisible, in themselves, and are discoverable, only by their effects, it is necessary to charge them with some substances which reflect the rays of light, in order to render them proper subjects of observation.—But the dust, powders, &c. used in the preceeding experiment, will not answer that purpose, as they fly off, instantly, upon their receiving, and condensing

* See *Franklin's* letters page 37. § 5. where he says, " Every particle of matter electrified, is repelled by every other particle, equally electrified. Thus the stream of a fountain, naturally dense and continual, when electrified, will separate and spread in the form of a brush, every drop endeavouring to recede from every other drop. But on taking out the electrical fire, they close again." To which may be added, that, if a small tin cup, filled with water, having a spout just big enough to let out the water by distinct drops, be electrified, the water will issue from the mouth of the spout in a diverging mist, so long as the cup remains charged, but as soon as discharged again, will fall in distinct drops as before.

round

round themselves a certain portion of the fluid : Instead of which, if fine limber threads are run through the balls, in various directions, and their ends cut off at equal lengths, these threads, as they cannot escape, shew, by their several directions, the tendencies of the electric atmospheres of the bodies they adhere to.

THIS being premised, we proceed to the following

EXPERIMENT. II.

LET a pellet of cork or pith, thus prepared, be suspended, and electrified ; the threads will diverge, equally, every way, from its center as at A Fig. 6. the electric atmosphere being equally condensed, upon every part of it, and equirepellent from its center outward. But if two such balls be suspended and electrified, and caused to approach each other, the threads of each, which happen to be next to the other, instead of standing out every way from the center, as before, will be incurvated towards the line of opposition, as at B and C ; whereby the reciprocal repulsion of their atmospheres is rendered visible, as the directions of the threads shew the tendencies of those atmospheres respectively ; from which it appears, that they recede from each other, as far as the mutual attraction subsisting between each atmosphere and its own ball, (which at first occasioned a condensation of the former round the latter,) will permit. But that the atmospheres do not wholly fly off, in consequence of this repulsion, is evident, as the threads continue in the same directions, until one, or both be discharged.

Query.

Query. DOES not this experiment abundantly confirm and illustrate the reasoning in page 29, relative to the passage of two Planets, or Comets, attended with large ærial atmospheres, by each other ; whose mutual effects are represented at C and D Fig. 3 ?

WE shall adduce one experiment more, before we close this subject, which may prove as entertaining to him who will be at the trouble of making it, as it is demonstrative of the principle under consideration.

EXPERIMENT III.

PROVIDE a wooden sphere, of four or five inches in diameter (call it A) ; let it be gilt, as the metal will better condense the electric fluid upon its surface ; also a small pellet, of cork, or pith of elder (which call B), strung, as in the last experiment, with a few threads, of three or four inches in length : Suppose A to represent the Sun, B, a Comet ; fix A on the wire of an electric bottle, and suspend B by a filken thread from a point, directly over the center of A, so as that, when neither of them is electrified, B may rest against A, a little below the level of its center ; and charge both ball and pellet. The mutual repellency of their electric atmosphere is so great, as that *that* of B is thrown off as far from A, as the mutual attraction between the pellet and its atmosphere will permit ; which attraction is at the same time so strong, as that, rather than suffer a separation, the pellet flies off with its atmosphere, to a certain distance from A, where its natural gravitation to the Earth is just balanced by the repellent force of the two atmospheres : There B remains

at

at rest, while its atmosphere retires as much farther as possible from A, without quitting it wholly ; instead of which it undergoes a longitudinal dilatation, in opposition to the center of A, as the atmospheres of Comets do, with regard to the Sun : This is evident from the directions of the threads, which, observed in a side view, bear a near resemblance to the tails of Comets. When the pellet is in this situation, blow it gently with a bellows, in a direction perpendicular to the line connecting the centers ; this will give it a projectile motion, which will be regulated by its common gravitation ; and as the center of A is directly under the point from which B is suspended, the latter will be carried round the former, as the center of its motion. Thus will this little Comet perform many revolutions round its electric Sun, and in every one, and through every part of each, the tail of threads will constantly maintain its opposition to it, as the tails of Comets do to the Sun in the Heavens.

THIS experiment was very agréably repeated with an artificial Comet, consisting of a small, gilt cork ball, with a tail of leaf-gold, about two inches and an half in length ; when, during the whole time of the experiment, in which it performed, at least, twenty revolutions, the tail, as nearly as the eye could judge, was constantly projected in the line of the opposition of the centers of the two balls ; the thread, by which the smaller one was suspended, either twisting, or untwisting, the same way, during the whole time. When thus in motion, if we raised the globe, the tail was depressed ; when it was lowered, the tail was elevated ; maintaining its opposition, in every situation.

BUT

BUT now, from these experiments, some may, perhaps, be inclined to think, that the electric fluid is the sole cause of the phænomena of the tails of Comets : That the Sun, as it is the grand source of light and heat, throughout our system, may be the fountain, from which this element, also, is somehow derived to its several globes : That Comets, for wise ends, unknown to us, have a larger share of this fluid than the Planets ; and that, when they approach the Sun's electrical atmosphere, their own are thereby repelled, as in the foregoing experiments ; and appear as lucid, diverging beams, like those which, in the dark, we see streaming from electrified points.

THIS hypothesis might indeed solve the phænomena of the cometic tails, provided the electric atmospheres or bodies, charged with that fluid, were visible in any of our experiments, even when made in the dark : But as that is never the case, unless the fluid be in motion ; and as the proof of the existence of such atmospheres, when at rest, depends solely upon their effects upon other substances, the hypothesis cannot be admitted. Were this indeed the *true* and *sole* cause of the phænomena, a Planet, near which a Comet might happen to pass, would be in a situation, truly hazardous ; for it is evident that the Planets (upon that supposition) are not accommodated with such vast electric atmospheres as attend the Comets ; consequently, have not the same proportion of that fluid condensed round them, but far short of it :— Therefore, whenever the electric tail of a Comet passed near a Planet, it would be attracted by *it*, be drawn aside, from its opposition to the Sun, towards *it*,
and

and upon *it* discharge the *surplussage* of its fire, that both might have equal, or proportional shares; which discharge, if we consider the snap of a small spark between two cork pellets, and enlarge the idea, proportionably, to that instantaneous cataract of fire which would necessarily take place between two Worlds in similar situations, we may well imagine would give an explosion, which nothing could equal, short of the final voice of an archangel; and, if it were not sufficient to rouse the ashes of the dead, might reduce the living to their primitive dust. But such a catastrophe, we have not the least reason to dread, from the neighbourhood of a Comet, unless we can suppose, that infinite wisdom and goodness would create one world, merely for the destruction of another; as we cannot conceive of any other ends, to which such huge electrical atmospheres could be adapted. Indeed the discharge would be equally fatal to both worlds; as it is certain from electrical experiments, that the effects of a stroke of lightning are the same, whether the flash proceeds from the cloud to the Earth, or is discharged from the Earth into the cloud, both of which have happened during the same thunder-gust; as appears from observations made by Mr. *Kinnerly* and Doctor *Franklin*,* communicated to the Royal Society. But to put this matter beyond all reasonable doubt, we may further observe, that if the phænomena of Comet's tails arose from the same cause, which renders the electric stream visible, when proceeding from a steel point, these tails would shine by their own light, as the electric fluid does, when in motion; whereas, an apparent obscuration or defect, in one of

* *Franklin's Letters*, page 116 and 129.

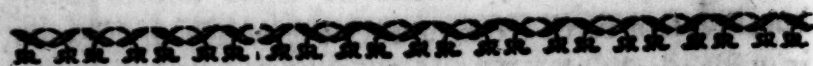
those

those tails, has been observed, which evidently arose from the shadow of its nucleus, which occasioned a partial eclipse of the tail, by intercepting the Sun's rays *: Consequently, the tail, as well as the head, shines with a borrow'd light, and both are visible, only by reflecting the rays of the Sun.

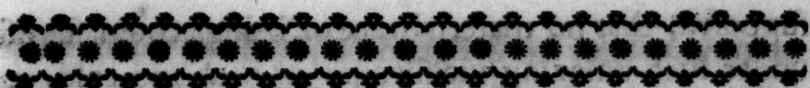
As the consideration of the properties of the electric element was introduced, merely, to *illustrate* the several propositions, and the conclusions resulting from them, contained in the foregoing pages; it was thought proper to add thus much upon that subject, in order to prevent the framing an hypothesis from those properties, which, instead of removing the fears of the timorous, upon the appearance of a Comet, (which was one design of this essay,) would naturally tend to increase their apprehensions. Whereas, upon the principles we have endeavoured to establish, the tails of Comets appear to be nothing more than air, immensely expanded and rarefied; through which the Earth might pass, with the utmost safety to its inhabitants. And, instead of these bodies being heralds, sent forth to denounce the wrath of Heaven, in which light they have been considered by the ignorant and superstitious, of all ages; or the immediate executioners of divine vengeance, as others have apprehended; we shall endeavour to prove, in the following pages, that Comets deserve to be considered in a more respectable light; and that their tails, however awful and portentous they have been esteemed

* Hevelii Cometographia Lib. XII. Page 898, quoted by Mr. Professor Wintrop in his 2d Lecture on Comets.

by some ; may be designed for, and are wisely adapted to, the truly god-like purposes, of rendering habitable a vast variety of Worlds ; and of affording a *comfortable* subsistence to innumerable species of beings, by which they are, probably, inhabited.



ESSAY



ESSAY

ON

COMETS.

PART II.

AS ancient geographers imagined the polar and equatorial regions, or the frigid and torrid zones of the earth, were uninhabitable, in consequence of the extremes of heat and cold, to which those climates are exposed : So, modern astronomers have passed a similar judgment upon the superior and inferior Planets, especially on *Saturn* and *Mercury* ; concluding, that our water would always boil upon the latter, and be frozen upon the former ; and that merely in consequence of their different distances from the Sun*. Whence it has been naturally concluded, that the textures of their various fluids, and of their inhabitants, to whose uses these fluids are adapted, are very different from what they are found to be upon our Earth : And, considering the near approaches of most Comets *to*, and the vast elongations of all their orbits *from* the Sun, it has been generally

* See Newt. Princip. Book III. Prop. VIII. Cor. 4.

supposed

supposed, that no material race of beings could subsist under such amazing vicissitudes of heat and cold; as those bodies must, from their different situations, necessarily be exposed to; consequently that they are uninhabited.

BUT the conclusiveness of this reasoning depends upon the truth of the following Proposition; advanced indeed by Sir *Isaac Newton*; but not supported by experiments, which were, with him, the *criterion veritatis*; viz. that, “*The heat of the Sun is as the density of his rays, that is reciprocally as the squares of the distances from the Sun.**”

HERE, we are again reduced to the disagreeable necessity, of dissenting from the opinion of the greatest GENIUS that ever dignified human reason; which, considering the justly celebrated fame of that illustrious author, may be stigmatized as ignorance or vanity: But it is hoped that the reader will wave that imputation, if he shall judge, upon the whole, that Sir *Isaac* himself would have altered his opinion, upon the evidence which we shall produce in support of the contrary position: We may, however, lay down this as a maxim, that, in the prosecution of any science, the progress of the mind must necessarily be retarded, in proportion to the *implicit* assent we give to the decisions of any man, however great. We shall therefore, without further apology, endeavour to prove that the heat of the Sun, as perceived by us, and as discoverable by its effects upon other substances exposed to his rays, does not depend upon the density of those

* Princip. under Prop. XLI. Book III.

rays only, though *they* are necessary to the very existence of that heat; but, *equally* upon the *concurrent* operation of another cause, which we shall presently consider; from whence it will follow, that these causes, wherever they co-exist, whether upon the Earth, or upon the heavenly bodies, will naturally produce similar effects.

In the mean time, before we engage in the discussion of planetary heat, as depending upon the several distances of the Planets from the Sun; it may throw some light upon this subject if we consider the portion of that heat which falls to our own share, and the distribution of it throughout the various climates of the Earth.

THE surface of the Earth has, by geographers, been divided into five zones, viz. one *torrid*, including all the regions between the tropics, upon every part of which the Sun shines perpendicularly twice every year: Two *frigid*, which are situated between the polar-circles and the poles, and endure the rigors of perpetual winter, as the former is always basking in a summer Sun: And two *temperate*, which experience the vicissitudes of winter and summer, and, in some parts of them, in their extremes; these are situated between the *frigid* and *torrid* zones, in both hemispheres. In the first of these, the seasons are much more uniform than in the others, the days and nights being nearly of equal lengths, the year round; and although the heat may, for a constancy, be greater therein than in any other climate, yet it is not liable to such great and sudden changes as are experienced in the temperate zones;

zones ; for, during a whole annual revolution of the earth, the difference of the degrees of heat, experienced in the *torrid* zone, as determined by the thermometer, are not so great as those which, sometimes, happen in the *temperate* zones, within the compass of a few hours* : Much more do they fall short of the extremes which are endured in the latter, in the opposite seasons of the year.† But what is above asserted of the *torrid* zone is to be understood only of the low, inhabited and cultivated countries, the mountainous regions with which those climates abound being excepted, for reasons which will hereafter appear.

THE axes of the several Planets whose diurnal rotations have been discovered are inclined, more or less, to the planes of their respective orbits ; consequently, their superficies are divisible into zones and

* One morning, in the winter of 1768, the mercury in *Farenheit's* thermometer was 5° below 0° ; by 11 o'clock the same day it had risen to 30° , and the next day to above 60° ; the difference being 65° in little more than 24 hours. Again, May 30, 1764, when the general election for the choice of councillors, for this province, was held at *Concord*, (a town about 20 miles west from *Boston*) the weather was (for the season) extremely hot ; but on the morning of the 1st June following, a severe frost cut off all the indian corn, beans and other tender annual vegetables, in that and the towns adjacent, for miles round. And on one Sunday morning, in the winter of 1759-60, a transition was made, instantaneously, from severe cold to summer heat ; to the great surprize of every one, and to the no small terror of many. The buildings suddenly smoked to such a degree, that, in some of the worshipping assemblies at *Boston*, the people suspected that the neighbouring houses were on fire ; and there was scarcely a person, who did not recoil from the heat, at the church doors, at the close of the service.

† One summer's afternoon in the year 1760, the thermometer, being exposed to the open air, in the shade, the Mercury stood at 102° . At another time, viz. in the winter of 1766-67, the Sun being an hour high in the morning, it was at 9° below 0° . These were probably, as great extremes as have been observed in this climate, the difference being 111° by the thermometer.

climates,

climates, corresponding with those of the Earth : And it is, at least, highly probable, that the various climates of each globe, during its periodical revolution round the Sun, experience as great vicissitudes of heat and cold as those of the Earth : Nor is it unlikely that, in the equatorial regions of the different Planets, there may be at the same time as great varieties in the degrees of heat they respectively enjoy, as there are in the temperate zones of the earth in the different seasons of the year ; but supposing all this, the inequalities in the distribution of heat to the several Planets and their various climates would vanish, when compared with those extremes which they would necessarily be exposed to, at their several distances from the Sun, upon the supposition that the Sun's heat were as the density of his rays ; for were that really the case, the heat of Summer upon *Mercury* would be about seven times as great as upon the Earth, and above twice as hot as boiling water with us. On the other hand our summer heat would be above ninety times greater than that of *Saturn*, the difference being more than seven times as great as that between our summer heat and the heat of red hot iron* : For it is undoubtedly certain, that the density of the Sun's rays is reciprocally as the squares of the distances from the Sun ; from whence the above conclusions must necessarily follow, if the heat be proportional to that density.

It is certainly then a question well deserving a philosophical enquiry ; whether there be not some me-

* Sir *I. Newton* concludes from experiments that boiling water is three times, and red hot iron about twelve times hotter than our summer heat. Princip. Prop. XLI. Book III.

dium provided in nature, which, being distributed in different proportions to the several Planets, may so attemper the heat of the Sun to their respective distances from him, as that the inhabitants of all may be equally happy in the enjoyment of it; and that one globe may receive as much benefit, and be exposed to as little injury, from that heat, as any other throughout the system. This indeed seems to be an object so worthy of the attention and providence of the great PARENT of the universe, that a philosophic mind would naturally embrace such an hypothesis, had it, but, the most slender evidence to support it. This medium, we shall find, is actually provided in the element of air, which is, in various proportions, condensed round, and constitutes the atmospheres of the Earth and the heavenly bodies.

As air is an element, to which we, and probably the inhabitants of the other Planets, are more indebted than is generally imagined; a short dissertation upon some of the advantages which accrue to us, and probably to them, from its presence, may be acceptable to the reader.

AIR is a grand medium in nature, through which an all-bountiful providence conveys to us many of the conveniences, comforts, and delights of life. Upon *Air* depends the ascent of vapors, and their condensation into clouds, whence they descend in dews and grateful showers, to refresh and fructify the Earth.— Upon *Air* we depend for the twilight, which affords us an agreeable gradation of shades from day to night; without which we should instantaneously plunge from the

the light of the Sun to midnight darkness; and again emerge from total darkness to the full lustre of day; which would be unsufferable to our organs of sight, upon their present constructure. *Air* is also the vehicle of sounds, whether articulate or inarticulate; consequently without it, we should not only be deprived of the artless melody of the woods, and of the raptures which accompany the masterly execution of musical composition; but, which is of infinitely greater importance to us; there could be no language, no communication of ideas, but by dumb signs; no liberal arts nor sciences in the world. Therefore if we could subsist without this element, all mankind would be like the unhappy few among us who are said to be born deaf and dumb.

It has already been shewn from experiments, that *Air* is necessary both to the support of animal life, and to the subsistence of flame: And how far the very being of fire, in any shape, and even of heat itself, may depend upon it, the reader may judge from the following experiments and observations of Mr. Boyle, related in *Shaw's* Abridgement of his Works.

“COALS,” says Mr. Boyle, “being put glowing into a receiver, in three minutes after beginning to pump, the fire totally disappeared.—Other coals being suspended, in the open air, at the same time, continued burning till a great part was reduced to ashes*. Lighted match was found more difficult to put out by exhausting the air than kindled charcoal, nevertheless in about seven minutes the

* Shaw's Boyle, page 429.

“ fire was extinguished, beyond the possibility of recovery by re-admitting fresh air.” Here we see that air is necessary to the subsistence, not only of flame, but of fire that emits no flame at all. To these we may add an easy experiment, which any person may try at his leisure, without the assistance of a pneumatic engine, viz. A composition may be made of allum and flour, which being well mixed together, reduced to a cinder in a crucible, pulverized, and otherwise prepared by a second heat, in a phial secured from the free communication of the external air, acquires an igneous quality, which, if the phial be kept stopped, it will retain unimpaired, even for many years; nor will it shew any appearance of fire more than any other matter confined in the same manner; but if at any time a few grains of it be let out upon any combustible substance in the open air, it will by the fresh air be instantly changed into fire, and kindle the substance upon which it falls. This powder is commonly called the black phosphorus. From a small quantity of it the experiment may be repeated with success for years together, provided care be taken, whenever the phial is opened to let out any of the powder, to stop it again immediately, to prevent the too free access of the external *Air*. Here we have a substance which has all the qualities of fire inherent in it, and retains them for a long time, and yet can never exhibit them but upon the admission of fresh *Air*. But to return to Mr. Boyle: In page 603 he concludes from experiments, which he had been making in condensed *Air*, that “ the consumption of matter by fire is greater in proportion to the quantity of *Air* contained in the (same) receiver; or rather
“ in

“ in a still greater proportion,” as he found by some subsequent experiments. Therefore, as the consumption of matter by fire, without flame, must be proportional to the intensity of the heat which consumes it, we may conclude from this last observation, that the intensity of the heat in any enkindled substance, is nearly proportional to the density of the surrounding *Air*, and depends in a great measure upon it. In page 604 Mr. Boyle concludes from other experiments, that “ fire is more easily kindled in *Air* much compressed, “ than in common *Air*. Now it is certain that, the more intense the heat, the quicker the same combustibles are kindled by it ; thus bodies, exposed to the foci of different burning-glasses, will take fire sooner from some than from others, according as the powers of those glasses to condense the Sun’s rays in their foci (*cæteris paribus*) are greater, by which condensation the heat is proportionably increased : But as in these experiments, made in condensed *Air*, Mr. Boyle kindled his fire with the rays of the Sun, thus collected in the focus of a burning-glass, and found, as above, that the same glass would more easily kindle substances, in compressed *Air*, than in common *Air*, it follows, that, the density of the Sun’s rays remaining the same, the heat with which they were accompanied was increased by increasing the density of the *Air* ; in like manner as if the density of the *Air* had remained the same, and the density of the rays had been increased, by using glasses of stronger powers : To which may be added that Mr. Boyle always found it extremely difficult, and sometimes impossible to kindle any substance whatever in an exhausted receiver, either by the rays of the Sun, or even by red-hot iron in contact with gun-powder itself. The conclusion is obvious to every capacity.

HAVING

HAVING thus exhibited to the reader an imperfect sketch of the principal uses to which our Air is subservient; wherein among other things, we have seen the necessity of its presence and co-operation in the production of heat by the rays of the Sun, in common experiments: We shall now in further prosecution of the subject, proceed to prove that the heat of the Sun, as enjoyed by the inhabitants of the Earth in general, depends, not only upon the density of the Sun's rays, but, equally, upon the density of the surrounding atmosphere. This we shall prove from the testimonies of travellers of the most undoubted reputations who crossed the seas, and undertook the most dangerous and fatiguing journies which, perhaps, have ever been performed by man, with no other view than to promote the cause of science; particularly *Don George Juan* and *Don Antonio de Ulloa*, and their attendants who were sent by the Courts of *France* and *Spain* to *South-America*, to measure a degree of the meridian under the Equator: In the execution of which commission, they were obliged to take their stations, and make their observations upon some of the highest mountains upon the Earth, viz. the *Andes* in the neighbourhood of *Quito*, under the Equinoctial:

It is well known that the tops of high mountains are at all seasons very cold, and are, for the most part, covered with snow the year round. But those above-mentioned, exhibit a scene truly curious; for from their summits to the plains below, inclusively, may be found at the same time, all the varieties of heat and cold, which are to be met with in every climate of the Earth, at all seasons of the year.*

* See *Ulloa's voyage to South-America*, Book VI. Ch. VII.

ONE observation made by *Don de Ulloa* upon the spot, is very remarkable, and much to the present point : He says, " the region of continual congelation began " upon the several mountains at the same height " above the level of the Sea, as determined by *equal heights of the mercury in the Barometer.*" But Sir *Isaac Newton* asserts, and deduces the certainty of it from " actual experiments," that " as to our own air, " *the density of it*" (i. e. at any height) " is as the " weight of the whole incumbent air, that is, (says he) " *as the height of the mercury in the barometer* "* It therefore follows, that the region of " continual congelation," or perpetual frost commenced upon all those mountains, where the air was of the same density. Above that *certain* height, the density of the air lessen'd, and the cold increased accordingly in severity, till the tops of the mountains presented all the horrors of winter, which are to be found in the polar regions. Whereas below *that* height, as the density of the air increased, from the increase of the incumbent pressure, the heat of the Sun also increased ; till the inhabitants of the plains below suffered all the inconveniencies of the torrid zone.

Now, the density of the Sun's rays being the same in the several cases, and the tops of the mountains being above the common region of the clouds, and consequently enjoying the presence of the Sun much more than the plains below ; it follows, that although the rays of the Sun may be the *sine qua non*, without which the inhabitants of the Earth would enjoy no heat at all, yet, the degree or *quantum* of their heat depends upon the density and co-operation of the aerial medium through which those rays are transmitted to them.

* See Princip. Book II. Prop. XXII. Schol.

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As the proportionality of the Sun's heat to the density of his rays, is a point, upon which, as proved or disproved, many curious questions in natural philosophy may turn, every argument which tends to determine that point will doubtless be acceptable to the reader; and if he should be already satisfied in his own mind, from the foregoing observations, that the heat of the Sun is *not* as the density of his rays simply, yet it is hoped that he will patiently attend to one argument more, which is drawn from Sir *Isaac Newton's* own principles, and naturally results from his computation of the amazing, inconceivable degree of heat, which must have been acquired by the Comet of 1680, at its perihelion, upon that supposition; which, though it has never been controverted, but generally allowed to be just, and quoted accordingly, must, if true, have occasioned the exhibition of some phænomena, which could not have escaped the notice of the many curious astronomers of that day. According to this great author's calculation, this Comet, by its near approach to the Sun at its perihelion, "acquired a degree of heat *two thousand times* greater than the heat of red-hot iron*"; but from previous experiments he concludes, that the heat of red-hot iron is but *twelve* times greater than that which dry earth acquires when exposed to the summer's Sun: With what an amazing lustre then must the Comet have glowed, merely from the heat it acquired during its proximity to the Sun! Therefore at its first appearance after the perihelion, it must have shone, not with a borrowed or reflected light, as it did before it arrived at that stage, but by its own newly acquired lustre, far exceeding (perhaps) the brightest Star in the Heavens; for if iron heated but *twelve* times more

* Princip. Book III. under Prop. XLI.

than

than dry earth exposed to a summer's Sun, becomes *red-hot*, and from that heat emits a splendor, independent of the Sun's rays, we may defy the human imagination to conceive of that splendor, when yet increased *two thousand* fold, and exhibited by a globe of equal dimensions with the Earth. Furthermore, Sir *Isaac* computes that a globe of red-hot iron equal to the Earth, or the Comet, supposed of equal bigness, would scarcely cool in *fifty thousand years*; therefore the Comet, being *two thousand* times hotter, if it were a globe of iron, would require 50000 multiplied by 2000, or *one hundred millions* of years to cool in. But if we suppose the Comet to cool *a hundred* times faster than an iron globe of the same magnitude, equally heated; it could not lose all its heat under *a million years**; nay, at the end of *five hundred thousand* years it would still be *a thousand* times hotter, and consequently brighter than red-hot iron. But as the period of this Comet is supposed to be short of *six hundred* years, [several appearances of Comets in past ages being supposed to be different visits from the same Comet, after intervals of *five hundred and seventy five* years;] if at every perihelion it acquired a degree of heat which it could not lose under *a million* years, and had short of *six hundred* years to discharge itself of the heat acquired at each revolution, how astonishing upon these principles must be the accumulations of its heat during those several revolutions! so great!

* This is the duration of heat generally assigned to this Comet, after its perihelion. But why a globe of earth should cool an hundred times faster than a globe of iron, as here supposed, no where appears, nor should the supposition be admitted, unless we suppose at the same time, that a globe of iron is one hundred times denser than a planetary globe; if then.

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that one would imagine, that for ages after its perihelion it would be visible merely from its own lustre, and that when, from its distance, its diameter would become insensible, it would still be seen as a lucid point, twinkling among the Stars : Yet so far was this from being the case, that in *three months* from its perihelion, viz. from 8th *December* to 9th *March* it totally disappeared, though the Earth was in a situation to view it for a considerable time after : Sir *Isaac Newton* says “ on the ninth and tenth of *February* to the naked eye the head appeared no more.”

THIS Comet, at least its tail, was discovered by Mr. *Flamsteed* two days after its perihelion, viz. on the 10th *December*; from which time till its total disappearance, it was constantly observed by astronomers; but none of their observations take notice of any extraordinary brightness it exhibited, more than is usual in the appearance of other Comets. Sir *Isaac* indeed observes, that “ in the month of *December*, just after “ it had been heated by the Sun, it did emit a much “ longer tail, and *more splendid* than in the month of “ *November* before, when it had not yet arrived at its “ perihelion.” But this he asserts of the tail only, for soon after he adds, “ the head of this Comet at “ equal distances from the Sun and from the Earth, “ appeared darker *after* its perihelion than it did *before*” : It is true he accounts for it by supposing the “ nucleus to be environed by a denser and blacker “ smoky than before.” But this is difficult to reconcile with what he says a page or two back, when speaking of the same Comet, viz. “ by so fierce a “ heat, vapors and exhalations, and every volatile “ matter

“ matter must have been immediately consumed and “ dissipated*”. May we not add, and the whole solid mass calcined or vitrified? Therefore, if that dulness in its appearance, after the perihelion, was owing to clouds and vapours, it is evident, from that great author’s own reasoning, that the Comet could not have been exposed to so great an intensity of heat, in that vicinity to the Sun; since all such heterogeneous exhalations must have been consumed and dissipated thereby, as fast as they arose from the head; if indeed any volatile or evaporable matter, or any degree of moisture whatever could have remained in the head after such an inconceivable ignition. Finally, had the Comet ever acquired so great an intensity of heat, it is probable the inhabitants of the Earth would never have lost sight of it to the end of time; much less would it have totally disappeared in three months after its perihelion.†

* If at the perihelion distance of this Comet from the Sun, viz. about 160,000 miles, or 1-6th of the Sun’s diameter above his surface (according to Sir *I. Newton*), the Sun’s heat is so fierce, as that “ all kinds of vapours and exhalations must be immediately consumed and dissipated thereby”, how is it possible for those clouds, (for such they undoubtedly are, see page 18) which appear, more or less, every day, like spots upon the Sun’s disk, and float in his atmosphere, at the height of but 7 or 8000 miles above his surface (see note * page 29), to remain undissipated for above twenty days together, as some of them most certainly do (see page 24)? Or rather, does not the continuance of those clouds, for so long a time, amount to a demonstration, upon Sir *Isaac*’s own principles, that no such heat exists, even within the denser regions of the Sun’s atmosphere.

† If the fixed Stars be supposed equal in magnitude to the Sun, and the Comet above-mentioned, equal to the Earth; the period of the Comet to be 575 years, and its body be supposed sufficiently luminous to render it visible in all parts of its orbit; it appears from Mr. *Bradley*’s determination of the parallax of the fixed Stars, after a long series of observations (see *Smith’s Opticks*, Vol. II. page 449 and onwards), that the apparent diameter of the nucleus of this Comet, must be much greater than that of the Stars of the first magnitude, even when most remote from the Sun and from the Earth.

SIR *I. Newton*, in making his computation of the heat sustained by this Comet, first took it for granted, "that the heat of the Sun is as the density of his rays," (as we have seen before): In the next place, he considered the density of these rays with us, at the mean distance of the Earth from the Sun, as a fixed and certain standard, with which the density of the rays at every other distance might be compared: Then, after exposing dry earth to the summer Sun, he compared the heat contracted thereby, with that of boiling water and red-hot iron, and found by experiments the proportional degrees of heat in them to be nearly as 1, 3, and 12 respectively: In the last place he considered the heat acquired by the dry earth aforesaid, as the standard of our summer heat, and annexed it to the mean density of the Sun's rays with us: And upon this foundation he seems to have constructed his general scale of heat for the solar system. But it is presumed that the reader is by this time satisfied, that the main proposition upon which that great author's reasoning was founded must fail for want of support, however just his conclusions drawn from it may be: For we now find regions of eternal frost under the equinoctial itself, the rigors of which are scarcely exceeded in the polar regions; and this, at the height of but two or three perpendicular miles above the common surface of the Earth, and where but few clouds interpose to hide the beams of the Sun. If therefore we suppose ourselves carried up forty or fifty miles higher, or to the very top of the atmosphere, we may well shudder at the idea of such a situation, even if exposed to the unclouded rays of a perpendicular Sun.

WE are now naturally led to consider some extensive purposes which the great Author of Nature probably had in view, when he formed the atmospheres of, and annexed them to, the several Planets and Comets of our System. We have seen from indisputable authority, that the density of the Sun's rays alone does not produce a competency of heat, for the comfortable subsistence of the inhabitants of the Earth, even in its hottest climates, but, that a certain density of air is equally necessary, for these rays to operate upon, and to co-operate with them, in promoting the various purposes of life and vegetation. This air we are abundantly furnished with from the atmosphere which surrounds us, the density of which at every height, is proportional to the pressure of the incumbent fluid. We may conclude from analogy that the atmospheres of the other Planets, and of the Comets, are designed for, and adapted to the same purposes for which the atmosphere of the Earth was originally provided : And if we suppose the general stock of heat, which falls to the share of any Planet, to be in a ratio compounded of the density of the Sun's rays and the density of the air upon the surface of the Planet, it is easy to conceive, that these globes may be severally furnished with such atmospheres, as may render them comfortable habitations, whatever their distances from the Sun may be. That the heat of the Sun is actually thus dispensed to the Planets necessarily follows from the experiments and observations contained in the foregoing pages, upon the supposition that they are surrounded with aerial atmospheres, suited to their several distances from the Sun ; that they have such atmospheres is already proved, and the Creator, has, doubtless

doubtless wisely proportioned their respective quantities and densities according to those distances.

THE *tails* of Comets are nothing more than expansions of their atmospheres, whose lengths depend upon their nearness to the Sun (as before observed) and decrease as they recede from the Sun, becoming invisible to us (generally) before their *heads* disappear : Therefore we have the highest reason to conclude that when these globes are in the most remote parts of their orbits, or at their aphelia, their tails wholly subside, and their atmospheres resume spherical forms, like those of the Earth and of the other Planets, surrounding their nuclei at equal altitudes in every part ; the Sun's atmosphere being too remote to have any sensible effect upon them by its repellency. The air must of consequence be prodigiously dense near the surfaces of their globes, being compressed by the weight of such a vast incumbent fluid ; whereby the Sun's rays, though weaker, or less dense than with us in the ratio of the squares of the distances, may, upon our principles, be rendered as active with them, and as productive of such degrees of heat as are necessary for the purposes of animal and vegetable life, as with us, or any other Planet of the System.

BUT, (as was observed by Doctor *Williamson*,) should these atmospheres continue of the same density, through all parts of their orbits, the degrees of heat which their inhabitants must undergo at their perihelia would be unsufferable : To prevent which, the great Author of Nature has made sufficient provision ; for as they approach the Sun, they are by the repulsion of his atmosphere (or some other cause equivalent to such supposed repulsion) gradually eased of that incumbrance,
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the cometic atmosphere being gradually rarefied and driven behind its body through vast spaces of the Heavens ; what remains from time to time being more and more rarefied by the increasing action of the Sun's rays upon it, and repelled as rarefied ; till at length, if they come near enough to the Sun, the inhabitants may have little more than pure æther to breathe in. Thus the Comet of 1769, (than which but few have gone nearer to the Sun) before it arrived at its perihelion, although it projected a most astonishing tail, yet the remaining atmosphere was dense enough to hide the nucleus it surrounded ; the Comet, when viewed through the best telescopes, presenting only a dubiously defined luminous appearance : But when it made its re-appearance in the evening about the latter end of *October*, its atmosphere had undergone so great a degree of rarefaction in passing its perihelion, that it was sufficiently pellucid to discover the nucleus, which appeared plainly and distinctly through it.

MAY we not then conclude, even with certainty, that as a Comet is perpetually varying its distance from the Sun, so the density of its atmosphere is continually changing through the various stages of its revolution ; and thence, that its inhabitants may at all times enjoy as much benefit, and receive as little injury, from the Sun's rays, as the inhabitants of any other Planet in the solar System ?

As the primary Planets revolve in orbits nearly circular, they have no occasion for such vast atmospheres as are necessary for the Comets in the remote regions of the Heavens to which they retire ; but are surrounded

rounded with such, as infinite wisdom saw best suited to their several distances from the Sun ; such as might have no redundancies to be thrown off in tails at one time more than another ; the nearly equal distances of each from the Sun, in the several parts of its orbit, requiring nearly an equal density of atmosphere at all times.

From the premises we may conclude, that the atmospheres of the inferior Planets are smaller, and those of the superior ones larger in *some* proportion, than that of the Earth, in order that their densities near their respective superficies, may be so proportioned to their several distances from the Sun, as that they may equally share the benefit of his rays. For want of proper astronomical observations, to determine this point with regard to the other Planets, we can pronounce with certainty only concerning *Mars* : As that Planet is further distant from the Sun than the Earth, his atmosphere, for the reasons above assigned, ought to be larger than our own ; accordingly it appears (from the observations referred to in Part I. Note * Page 12) that the height of his atmosphere above his surface is at least equal to two thirds of his diameter ; which is much greater than that of the Earth, though it falls vastly short of those of the Comets. Observations of future occultations of fixed Stars by *Jupiter*, *Saturn* and the other *Planets*, made with better instruments, may possibly determine this point with regard to them also.

SEVERAL objections may be raised against the principles advanced in this Essay, to all which we hope to give satisfactory answers. As

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1. IT may be objected, that, as the *light* of the Sun is confessedly proportional to the density of his rays, that is inversely as the squares of the distances from the Sun, the inconveniencies arising therefrom to the inhabitants of the Comets, at their *peribelia* and *aphelia*, might be nearly as great as those which would arise from the Sun's *heat* were it distributed in the same proportion; or at least, if it did not render the Comets uninhabitable, would make the conditions of their inhabitants, at times very uncomfortable. For example, were the light of the Sun adapted to their various purposes, at their *mean distances*, at their *aphelia*, they might not enjoy a sufficiency; and on the contrary at their *peribelia*, the splendor would be unsufferable.

THIS objection, it is presumed will vanish upon a careful attention to the structure of the eyes of terrestrial animals, whose pupils contract or dilate involuntarily, according as the density of the rays which pass thro' them and fall upon their retinas is greater or less, whereby more or fewer of those rays are admitted, as may be requisite for distinct, inoffensive vision: Thus most persons can see to read by candle light near as well as by day light, whereas the quantities of light reflected from objects in the two cases scarcely bear any proportion one to the other. But the aperture of the pupil is much greater in the former than in the latter, and more rays in proportion are consequently admitted. Moreover, there are some animals with us which retire to their holes and caves at the approach of day, whose purposes are as well answered by the glimmer-
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ing light of the Stars, as those of others are by the presence of the Sun ; there are yet others which can behold the Sun in his meridian splendor, without offence. Now if we only suppose that the inhabitants of Comets in general have, in the original formation of their optic organs, the power of contracting and dilating their pupils, according to the strength or weakness of the light which is transmitted through them, we may easily conceive, that the rays of the Sun might be no more offensive to them at one time than at another ; for at their aphelia their pupils might be dilated to their utmost extent ; on the other hand, at their perihelia, they might be contracted to physical points, if the splendor of the Sun so required, whereby a proportionally smaller quantity would be admitted.

THE light of the Sun which the Cometarians enjoy at their aphelia is indeed much greater than we should be apt to imagine ; for let us consider the Comet of 1680, whose period is the longest and its aphelion distance the greatest of any one known, being (according to Dr. Halley) to the mean distance of the Earth from the Sun nearly as 138 to 1 ; but from the reasoning of Doctor Smith, in his optics it appears, that the proportion of our day light to moon light with a full moon, is nearly as 90 000 to 1 ;* and the light of the Sun upon the Comet at its last mentioned stage is to his light with us but as about 1 to 19000, therefore if we divide 90 000 by 19 000 we shall find that Moon-light with us is to Sun-light upon the Comet, nearly as 1 to $4\frac{3}{4}$, and consequently that the light of the Sun

* Smith's Opticks, Vol. I. Page 29.

enjoyed

enjoyed by the inhabitants of that Comet at its aphe-
 lion is nearly five times as great as the light of our full
 Moon. But it is still much greater upon account of
 the largeness and density of the atmosphere ; for it
 is certain, that our day light, which is equally diffu-
 sed upon all terrestrial objects, and renders them vi-
 sible ; depends upon the reflection of the Sun's
 rays, from the atmosphere, together with the hete-
 rogeneous corpuscles floating in it ; without which all
 such objects would be as obscure as at midnight, even
 with the Sun shining in full splendor above the hori-
 zon ; excepting those upon which the direct rays of
 the Sun might fall, or such as might be faintly illumi-
 nated by the reflection of those rays from neigh-
 bouring objects : The Heavens would appear perfectly
 black, and the smallest Stars would appear, at noon-
 day, which is prevented, only, by the illumination of
 the atmosphere. The beautiful azure, which we ob-
 serve in the Sky, after the atmosphere is purged of its
 vapors, by a storm or thunder-gust, arises from the
 appearance of this black Sky, through the air, which
 is now become more transparent, than when charged
 with a heterogeneous collection of opaque corpuscles.

THE atmospheres of Comets, being much larger and
 denser than that of the Earth, reflect a much greater
 proportion of the Sun's rays ; their hemispheres next
 the Sun must therefore be more illuminated, and their
 day light increased, in the same proportion ; although
 the light arising from the direct rays of the Sun would
 be considerably weakened thereby.

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THIS reasoning may be illustrated by calling to mind the effects of two great eclipses of the Sun, one of which happened on the 5th or 6th day of August, 1766 ; the other on the 19th day of January, 1768 ; which effects, most persons among us, whose attention was turned that way, may recollect ; during the former the air was very clear, and the sky cloathed in a fine blue, excepting, here and there, where a few summer clouds were scattered : In the midst of this eclipse the air was darkened to such a degree, that, although the Sun shone unclouded, a sickly gloom seemed to spread over the face of nature. In the latter, (though a much greater eclipse) the air was full of vapors, the reflection of the Sun's rays from which was so copious, as to render it offensive to the eyes to look at the Heavens, before the eclipse began, and in the middle of it, the darkness occasioned thereby would scarcely have been noticed, had not the eclipse been known beforehand.

THE inhabitants of Comets enjoy another advantage from their great atmospheres, which is peculiar to them alone ; for, in the hemisphere turned from the Sun, they can have no dark nights like those of the Planets ; but, in consequence of the reflection of the Sun's rays from those atmospheres, must be favoured with perpetual twilight if not day light ; for a cometic atmosphere is enlightened by the Sun by night as well as by day, excepting only a column, which is nearly cylindrical at the aphelion, whose base is a great circle of the Comet, and whose altitude is equal to the height of the atmosphere ; which, (considering the
great

great extent of the latter,) bears but a small proportion to the whole atmospheric hemisphere; this column includes that part of the atmosphere which is eclipsed by the shadow of the globe itself, and, if the diameter of the atmosphere is equal to ten diameters of the globe*, does not contain $\frac{1}{100}$ th part of the whole visible hemisphere; and is still less upon account of the refraction of the Sun's rays, which shortens and contracts the cone of the shadow. Whence it is probable that the darkest nights of the Cometarians, at their aphelia, are much lighter than our brightest moonlight nights. But this is submitted to the judgment of the reader.

2. It may further be objected; that if the atmospheres of Comets undergo such amazing rarefactions and condensations, as they necessarily must, from the alternate projections and retractions of their tails, it is difficult to conceive that they can at all times be fit for the respiration of their supposed inhabitants.

THIS objection might, perhaps, have remained unanswered, had it not been for the genius of that truly great philosopher Doctor *Edmund Halley*; who, if he was not the original inventor of the *diving-bell*, yet, by a sagacity peculiar to himself, improved it to a degree of perfection, which might, before, have rather been wished for, than expected.† In this *bell* persons may be let down with safety to the bottom of the sea; but the included air differs in density at every depth below the surface of the water. At the depth of

* See Page 14.

† See Jones's Abridgment of Philos. Trans. Vol. IV. Page 188, and onward.

thirty-two or thirty-three feet, as the air may occasionally change, or less, in proportion as salt water is heavier than fresh, the density of the air within the bell is double the density of the external air; at double that depth the density is triple; at three times, four-fold, and so on. Now if the bell be let down without proper precaution, the too sudden condensation of the air within, would give the adventurers extreme pain, as they sometimes found by experience; and should the bell sink suddenly to the bottom of the sea, the consequence might be fatal to them; for the same reason that a square case-bottle, filled only with common air above the surface of the water, and corked tight, if it were let down with the divers in the bell, would from the increasing pressure of the condensing air without it, be crushed inwards, and broken in pieces, in the same manner as if the air in the bottle had been exhausted by an Air-Pump above the surface of the water; which effect would be prevented by the smallest hole in the cork, provided the bell were let down leisurely, so that the air as it condensed without, might gradually insinuate itself through the hole into the bottle: On the contrary were the bottle corked at the bottom of the sea, and the bell drawn up from the depth of nine or ten fathoms; before the bell could arrive at the surface of the water, the bottle would burst outwards, from the expansive force of the condensed air within it; which might also be prevented by a similar precaution. And it is doubtless from the latter cause that some persons who have ascended to the tops of high mountains, have been seized with reachings, vomitings and other inconveniences

niences related by travellers ; the external air of the atmosphere at such heights being too rare to counteract by its pressure, the expansive force of the denser air which is interspersed throughout the various vessels and organs of animal bodies.

BUT Doctor *Halley* testifies from his own experience, that “ if the diving-bell be let down (or drawn up) “ gradually, about twelve feet at a time with an interval of but a few minutes between, no inconvenience would follow” ; as the several organs of the body would by degrees be inured to the density of the air, as it increased or decreased at the several depths. The Doctor tells us, that he himself was hours together at the bottom of the sea in nine or ten fathoms of water ; and felt himself as well as if he had been all the time on board the ship : But the density of the air he then breathed, must have been more than three times as great as that of the air above the surface of the water : In other words, he then breathed in air, compressed by the weight of between three and four of our atmospheres instead of one, and of ten or a dozen such as *Don de Ulloa* breathed in, when upon the tops of the mountains of *Quito*, without any inconvenience. Therefore, if time sufficient be allowed for the air, included in the several vessels of the human body, gradually to contract, expand or otherwise accommodate itself, to the increasing or decreasing density of the exterior air ; no bad consequences or even inconveniences are to be apprehended, although the difference of density be exceeding great.

BUT by the gradual and regular approach of any Comet to, or recess from its perihelion, (at and near which its velocity

velocity is greatest and the consequent changes in its atmosphere are most sudden of all) the increase or decrease of its atmosphere, is much more regular, uniform, and insensible to its inhabitants, than any increase or decrease of the density of the air can be in the diving bell by Doctor *Halley's* method ; for by the latter, a degree of rarefaction, or condensation, is effected in a few minutes, which might not take place in the cometary atmospheres under some days.

PERHAPS enough has been already said to remove every material objection ; but if any difficulties yet remain, in the mind of the reader, on account of the vast changes which the several climates in each, and the atmospheres of all Comets must necessarily undergo, in the various parts of their orbits ; the following additional observations are submitted to his consideration ; which may tend to lessen those difficulties, if they do not wholly remove them, viz.

As a Comet approaches its perihelion, that hemisphere of its atmosphere which is next to the Sun, being more immediately exposed to his rays, will feel the effects of his neighbourhood sooner than the opposite hemisphere, and consequently will be warmed, rarefied, and thrown off behind the Comet by the repulsion of the Sun's atmosphere, sooner than the other ; the colder and denser parts of the fluid will of course continually flow in from the other side of the Comet to supply its place, in order to preserve, as near as may be, an equilibrium ; in consequence of which there will be a constant succession of the cooler air from thence ; whereby the inhabitants on the hemisphere next the Sun may be continually

continually refreshed with gales of wind during that vicinity, which would increase till the Comet arrived at its perihelion, when their velocity would be greatest of all ; but even then they would not (from this cause) blow in sudden violent gusts like our hurricanes, but steadily, unless disturbed by causes from within the Comet's atmosphere ; besides, as the velocity of the current increased, the density of the fluid would lessen from the increasing rarefaction, whereby its momentum might continue nearly the same ; for this momentum would be in a ratio compounded of the velocity of the fluid and its density together ; and as the violence of our high winds, and their consequent effects depend, not upon the velocity, merely, but upon the momentum of the current, this brisk circulation of the cometic air may, (however great we suppose its velocity) be rather grateful than injurious to the *Cometarians* : And how unfit soever the air in such a rarefied state might be for their use, if stagnant, yet, when thus put in motion, it may be rendered sufficiently active to answer all the purposes of respiration. This reasoning is confirmed by daily experience : For it is not an uncommon thing for people of tender frames to faint in a close hot and rarefied air ; and as the fan is generally near at hand, it is as common for the by-standers to apply it to their faces, which, by giving a brisk motion to the air, without any alteration of its density, generally revives them, in a short time, even when no other remedy is at hand.— This brisk motion of the air would also remove or prevent the disagreeable sensations of heat which the

cometary

cometary inhabitants might otherwise suffer from an exposure to the Sun's rays at their perihelia : For, if a person sit with his face uncovered before the scorching blaze of a common fire, the motion of the air excited by a common fan, even without hiding the blaze from the face, is sufficient, not only to make the situation comfortable, but to change the painful sensation to an agreeable coolness : As any one will find upon trial.

If we suppose that every Comet has a diurnal rotation round an axis of its own, the inhabitants may enjoy grateful vicissitudes, from the alternate absence and presence of the Sun ; and if we further suppose this diurnal motion to be performed contrary to its apparent heliocentric motion ; the returns of day and night would be quickened as it approached the Sun, from the increase of its angular velocity round that globe, whereby the presence of the Sun, in that neighbourhood, would be of shorter duration, upon any one part of the Comet, and his heat might be rendered still less irksome to the inhabitants, on that account. It is true, no discovery has been made of any such diurnal motion, but as all the primary Planets, so far as our observations can reach, are discovered to have such motions, we may well be allowed to suppose that the Comets are not without them ; especially now we are endeavouring to prove their habitability, to which this motion is perhaps as necessary as to the habitability of the primary Planets. These rotations have been already discovered and determined in *Venus*, the *Earth*, *Mars* and *Jupiter*. *Saturn*, though a vast globe in itself, is so remote, and *Mercury* is so near the Sun, and so very small, that this motion has never

never been discovered in either, by our best instruments, but is justly inferred by analogy ; which method of reasoning will equally extend to the Comets of the System. The diurnal motions of the Planets indeed are performed nearly in the same directions with their annual, both motions in all, as far as they have been discovered, being direct, or from West to East, whereas the diurnal motions of Comets, according to the foregoing supposition, are performed contrary to this rule : But this is no objection against the hypothesis ; for Planets and Comets differ as widely, in almost every other particular ; the annual motions of the former (as now observed,) are all direct, and are apparently confined within the limits of the zodiac, the latter move indifferently in all directions through the Heavens ; the periodical revolutions of the former are made in orbits nearly circular, those of the latter are prodigiously excentric, and nearly parabolical ; all which seem wisely to be ordered, that a multitude of Worlds may exist at the same time, and be enlightened, warmed, and rendered prolific, by the rays of the same Sun, without interfering in their motions, or disturbing the harmony of the System.

To illustrate the reasoning in pages 78. 79, Fig. 5 is added ; in which let S represent the Sun ; to which Comets in general, though perhaps equal in magnitude to our Earth, are, without a *figure*, but as *drops of the bucket*.* Let C represent a Comet with its at-

* In the figure the speck at X and the dots round it, upon the surface of the Sun S, will give a pretty just idea of the comparative magnitudes of the Sun and Comet, and of their atmospheres ; the dots at X representing the Comet's atmosphere, A-A A, &c. the atmosphere of the Sun.

M

mosphere

mosphere and tail, the dark curve line *ckdgb* on one side, and *ciaef* on the other, may serve to give an idea of the motion of a parcel of the cometary air from its more condensed state behind the Comet at *c*, through its various stages of rarefaction and repulsion; as that part of the atmosphere next the Sun, viz. that in or near the line *S b* which connects the centers of the Sun and the Comet, is rarefied, the denser air from behind at *c* must necessarily flow in to preserve as near as possible an equilibrium, and continue so to do as long as the rarefaction continues to increase. The air next the Sun being thus rarefied, that at *c* would take a turn round the nucleus through *k* and *i*, but before these separate parcels came to *d* or *a* the rarefaction would so increase, that they would begin to ascend, and as they ascended, at *a* and *d* they would repel each other; they would still keep rising by their increasing rarefaction, through *S b* as through a funnel, and increase in their mutual repellency as they receded from the center of the Comet, till at length at *l* and *m* the repellency of the Sun's atmosphere would compel them to retire through *g b* or *ef* whence they would proceed to the extremity of the tail, the remaining parcels of air in the same cometic hemisphere would take a similar course (as represented by the faint strokes in the figure) whether their distances from the Comet's surface were greater or less, till at length the rarefaction of the Comet's atmosphere would become as great, as the repulsive power of the Sun's atmosphere could effect, or the Comet's vicinity to the Sun, require.— We shall offer one observation more, for the consideration of the reader before we close the subject, viz.

WHEN

WHEN the air of our atmosphere appears by the thermometer to be extremely cold, it does not affect the senses so disagreeably, if the atmosphere be in a calm stagnant state, as at other times, when the mercury is ten or even twenty degrees higher, (and consequently the weather warmer) with a brisk wind, as has been frequently observed by those who attend to their thermometers. Now when a Comet is at its greatest distance from the Sun, its atmosphere, being uniformly condensed round its globe, might settle into a dead calm, for any disturbances it could receive from without : For whatever influences baneful or salutary, the heavenly bodies may reciprocally communicate while in the neighbourhood of each other, the Comets in their aphelia, are removed to such inconceivable distances from all the other globes of the System, that their mutual effects, physically considered must vanish. And in so calm an atmosphere, of so great a density, illuminated by the Sun's rays, the inhabitants of the Comets may, even when most remote from the Sun, be as warm, or at least as comfortable as the inhabitants of the Earth, or of any other Planet.

THIS subject cannot be better closed than in the words of Doctor *Williamson*, viz.*

“ ONE of the primary ideas we form of the
 “ supreme Being is, that he is the source of life, intelli-
 “ gence and happiness, and delights to communicate
 “ them ; the Earth we tread, the water we drink, and
 “ the very air in which we breathe, swarm with living

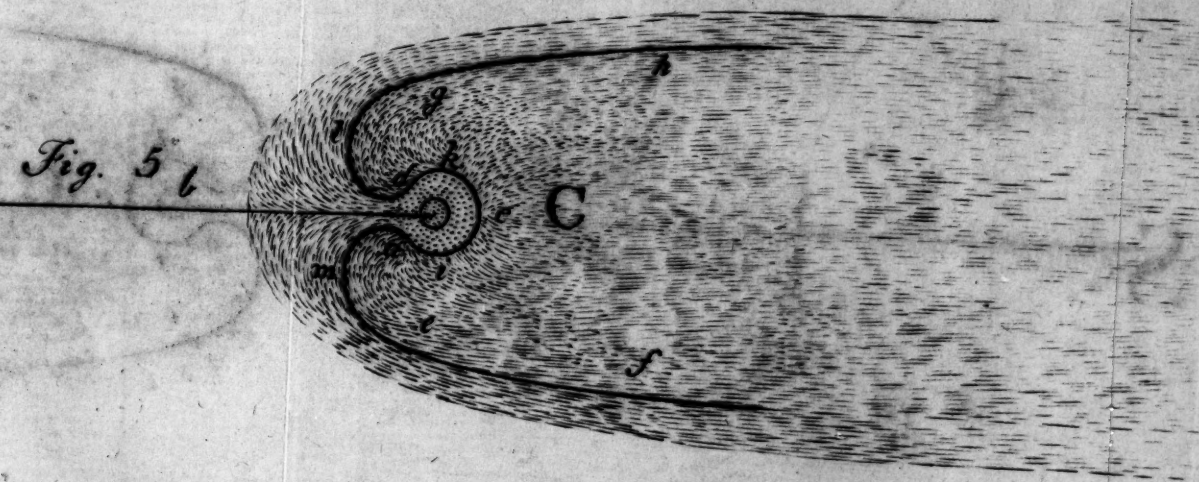
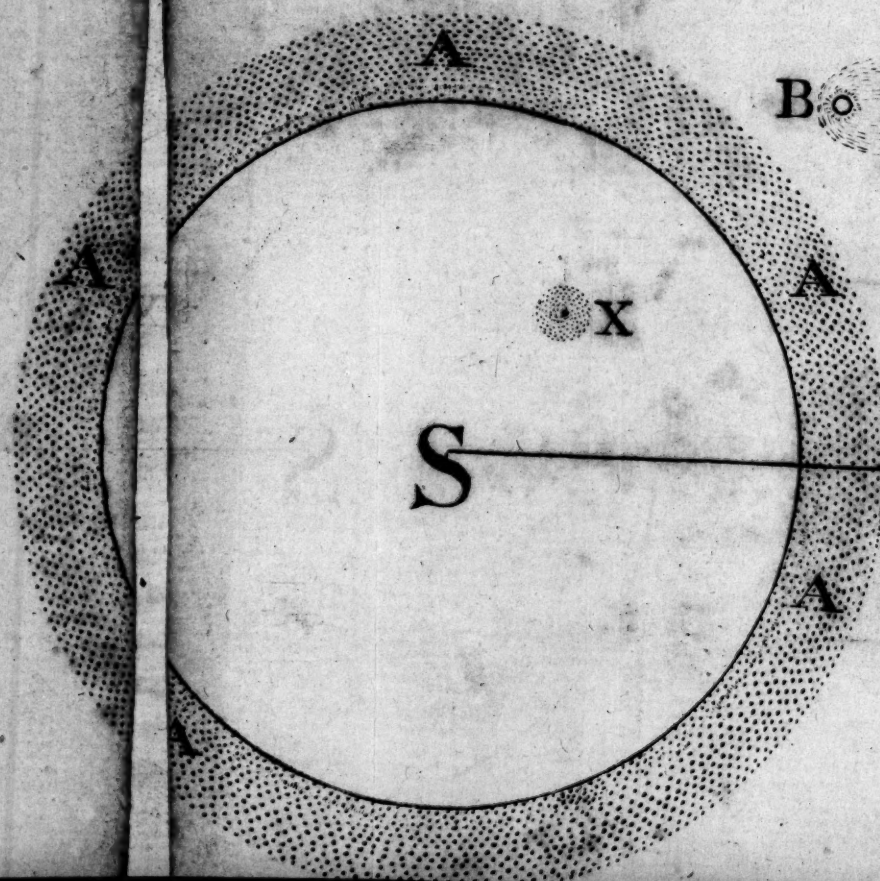
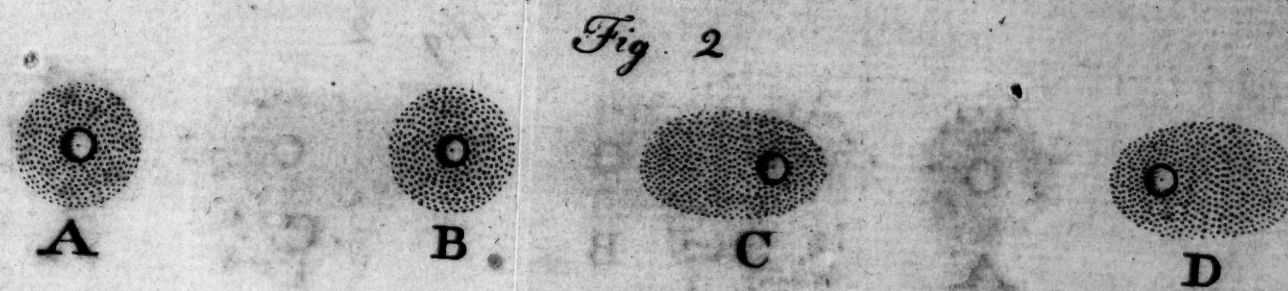
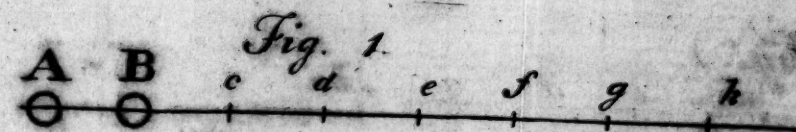
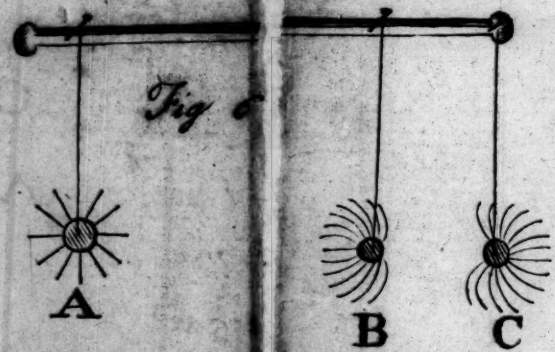
* See Transactions of the American Philosophical Society of Philadelphia.---
 Appendix page 30.

creatures,

" creatures, all fitted to their several habitations.—
 " Are we to suppose that this little globe is the only
 " animated part of the creation, while the Comets,
 " many of which are larger worlds, and run a nobler
 " course, are an idle chaos, formed for the sole pur-
 " pose of being frozen and burnt in turns?—We
 " cannot admit the thought; the Comets are doubt-
 " less inhabited."



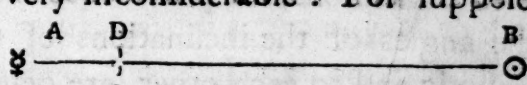
APPENDIX.



A P P E N D I X.

IF we suppose all the solid globes of the solar System to be annihilated, their atmospheres remaining ; the power of gravity, which had theretofore condensed them round their respective orbs, ceasing, they would immediately expand themselves *quaquaversum*, in consequence of the mutual repellency of their particles, till the whole space in which the bodies of the System had revolved, was equally filled with the fluid, and when its density became equal in every part, the whole would be at rest.

So, *vice versa*, if we suppose such a fluid, to have been the first material substance in the order of creation, equally diffused, in that rarefied state, throughout the mundane space ; next after it, the several masses of the Sun, Planets and Comets, nearly about the same time with each other : This fluid, though its particles are in a state of mutual repulsion, yet as they are in the common state of gravitation to the other bodies of the System, would be attracted by the several globes, every particle moving towards that globe, which should have the balance of attraction in its favour.

Mercury's atmosphere, by reason of its neighbourhood to the Sun, and the smallness of his globe would be least of all and very inconsiderable : For suppose a right line A B.  drawn from the center of the Sun to the center of *Mercury*, to be so divided in D, that the part next the Sun may be to the part next *Mercury* in the subduplicate ratio of the quantity of matter in the Sun

Sun to the quantity of matter in *Mercury*; every particle between D and B would descend to, and be condensed round the Sun, and those only between D and A to *Mercury*; and it appears by computation that $DB : DA :: 3693 : 1$ nearly, and in all oblique directions the particles, whose distances from the Sun and *Mercury* were proportionably greater or smaller, would descend to, and condense round one or the other; unless drawn aside by some other Planet: What is here said of *Mercury*, is equally applicable to the other Planets; and as the attraction of the Sun is vastly greater than the united attractions of all the Planets together; so, in every part of the System, where the attractive power of the Sun might be greater than that of any neighbouring Planet; the fluid occupying that part of the space, would descend and join the Sun's atmosphere; while the rest would be continually condensing round the Planets, till at length the several globes would be accommodated with their proper atmospheres, when the Heavens would be left a perfect vacuum for the various bodies to revolve in, without the least resistance.

If the Comets be supposed to have been created and projected in their several orbits, at their aphelia, or at their greatest distances from the Sun, it may be easy upon this hypothesis to account for their having atmospheres so much exceeding those of the Planets in their dimensions, for providence has so ordered it, that the angles of the inclinations of their orbits to the ecliptic and to each other are generally very great, and their motions are directed to all parts of the Heavens indiscriminately, whereby their distances from the Planets and from each other at their aphelia, are

are great beyond human conception ; consequently they were at liberty to share amongst themselves, without any molestation from the Planets, all that part of the fluid, which filled the vast spaces of the System, without the planetary regions ; therefore if the hypothesis be granted, they must necessarily have such atmospheres, as, in fact, we find they have, and which, in their descent through the planetary spheres, are, by the (supposed) repulsion of the Sun's atmosphere, driven to such astonishing distances behind them, as occasion may require. Those whose aphelion distances were greatest, being more solitary, would condense round them the greatest atmospheres, and such, their greater distances from the Sun would require, upon the foregoing principles, to make them comfortable habitations. As the lengths of their tails would probably, at equal distances from the Sun, be proportional to the quantities of this repellent matter contained in their atmospheres respectively, it may not be impossible to form a rational conjecture of their real aphelion distances, by observing the apparent lengths of their tails, when at equal distances from the Sun, in their descent, and thence computing their real lengths, and comparing those whose aphelion distances are unknown with those which are already determined ; and as nearly as we can by this method come at their greatest distances from the Sun, so nearly may we (by comparing their computed trajectories, with those distances,) determine their mean distances and periodic revolutions. But this is humbly submitted to better judges, and is designed only as a hint for future inquiries.

F I N I S.

